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TABLE OF CONTENTS.

Page.

LEADING ARTICLES:

The Meadow St. Reinforced-Concrete Arch Bridge, Pittsburg, Pa. (illustrated); N. S. Sprague, M. Am. Soc. C. E. 583

Wire Drag Work of the United States Coast and Geodetic Survey (illustrated) 588

Further Tests on the Effect of Electric Currents Upon Concrete and Steel (illustrated); U. James Nicholas 590

The Briquetting of Iron Ores; C. de Schwarz 593

The Western Pacific Ry. (illustrated) 595

Puzzolan-Portland Cement; An Improved Hydraulic Cement; Edwin Duryea (illustrated) 596

The Function of the State Engineer in the Arid and Semi-Arid States; Samuel H. Lea, M. Am. Soc. C. E. 598

The Clark Quick-Dumping Steel Ore Car (illustrated); James S. Martin 603

A German Sanitary District and the Imhoff Sewage-Purification Tank (with introduction by R. Hering, M. Am. Soc. C. E.; illustrated); Charles Saville. 604

The Cape Cod Canal (illustrated); Jacob W. Miller 608

Notes from the Engineering Schools 608

Page.

EDITORIAL 599

The Federal Prosecution of Stock-Selling Swindlers—Hydrographic Surveying with Sweeps and Its Relation to Safety in Water Transportation—The Growing Interest in Iron Ore Briquetting.

Revolutionary Improvement in Sewage Disposal 599

Can the "Principles of Scientific Management" be Applied to Railway Operation? 600

LETTERS TO THE EDITOR 601

The Physical Meaning of Entropy; A. L. Menzin—Prof. Kent's Entropy; Sidney A. Reeve—The Accuracy of an Approximate Method of Drawing an Arc of Definite Length (illustrated); Arthur H. Morse—Water Sign-Posts in Deserts (illustrated); L. R. W. Allison—Checking the Spread of Forest Fires by Broad Fire Lanes; W. S. Wheeler—Notes and Queries.

ENGINEERING NEWS OF THE WEEK 609

PERSONALS 610

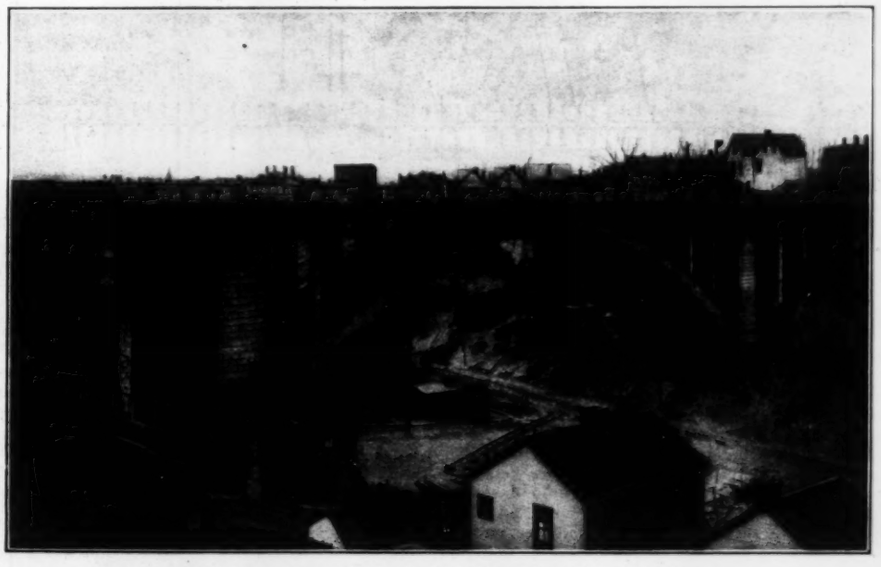
ENGINEERING SOCIETIES 610

The Meadow St. Reinforced-Concrete Arch Bridge, Pittsburg, Pa.

By N. S. SPRAGUE,* M. Am. Soc. C. E.

For the proper development of a city like Pittsburg, whose topography is rugged and broken and whose area is cut up and separated and made inaccessible by the presence of deep ravines and valleys, the construction of highway bridges or viaducts connecting the different isolated districts is essential.

Some years ago, when it was desired to develop and expand into new districts, the policy of the City was to provide communication by means of wooden viaducts. While the first cost of a structure of this type was less than the steel bridge, it was found expensive to maintain and its integrity uncertain after a few years of service. Consequently this type of construction was replaced by steel viaducts. The local conditions of the atmosphere peculiar to the Pittsburg district, containing as it does a large amount of sulphur, has an injurious effect and corrosive action upon steel, so that with the advent of reinforced concrete, with its moderate cost and its application to bridge construction, the use of this material has been adopted for the construction of a number of small single span highway bridges and for larger structures where found desirable.



MEADOW ST. BRIDGE, PITTSBURG, PA., SPAN 209 FT.

The Meadow St. bridge is located in East Liberty, a suburb of the City, and connects a large residence and semi-business district on the east with a purely residence district on the west. The bridge crosses a large ravine at a point about 2,300 ft. south from its junction with the main ravine, which is locally known as Negley Run.

The necessity for a bridge in this location has been apparent for a number of years and there has been an insistent public demand from this district upon the Department from time to time to build a bridge connecting these two sections, so that in 1901, plans were made providing for a steel viaduct 385 ft. long, 42 ft. in width, having a 30 ft. roadway with two 6-ft. sidewalks, supported on four towers and one A-frame. The estimated cost of this structure was $32,000. Funds were never provided for the carrying out of these plans and the agitation apparently died out until the year 1908, when $65,000 was appropriated for the building of the Meadow St. bridge.

In order to design and prepare plans for these structures additional employes were necessary, authority for which was not obtained until May, 1909, and contract plans were started for the Meadow St. bridge shortly thereafter.

Description of Bridge.

The Meadow St. bridge is the largest reinforced-concrete bridge in this vicinity, and is the first bridge of its kind built by the City. For this and esthetic reasons special consideration was given to such artistic features of the bridge as were possible, without materially increasing the cost of the structure, in order to give the bridge a pleasing appearance.

The plans (Fig. 2), provide for a reinforced-concrete arch bridge 454 ft. in length, having a 30 ft. roadway and two 10-ft. sidewalks, with a maximum clear height at the center of the arch of 78 ft. The length of the main arch span is 209 ft. with a rise of 46.14 ft. and consists of three arch ribs, the two outside ribs being uniformly 3 ft. 9 ins. in thickness and the central rib 5 ft. and all three ribs having a depth varying from 5 ft. at the crown to 6 ft. 2 ins. at the springing line. The profile of the slopes and the location of proposed streets in the valley determined the length of this span.

The main arch ribs are connected at the panel points by 26 horizontal struts, each 12 ins. in width. The depth of these struts is the same as the arch ribs except near the crown of the arch. These struts are to provide additional lateral strength, against wind pressure and possible indeterminate secondary stresses. The main arch ribs spring from two main piers of cellular construction 37 ft. 9 ins. long and 14 ft. in width.

Between the main piers and the abutments are three viaduct approach arches, each having a span of 21 ft. Calculations were made for two arch spans between these points, but it was found desirable to reduce the arch thrust at the top of the main pier as much as possible. For this and esthetic reasons, and also from the standpoint of economy, three spans were decided upon and adopted.

The abutments are U-shaped, of cellular construction, the horizontal thrust from the approach arches being transmitted from the face wall of the east abutment by partition walls extending from the face to a point where the line of pressure intersects the rock surface. At the east abutment the thrust from the approach arches is transmitted to the face wall, which is reinforced by a buttress back of each main arch rib. The front and side walls of the east abutment are 13 ins. in thickness and are designed for vertical pressure and also to act as a beam if necessary, the top of the walls being covered and tied together with a reinforced-concrete slab, varying in thickness from 8½ ins. at the center line of bridge to 12¼ ins. at the curb lines, similar to the type used on the main spans, and extending 28 ft. back from the face of the abutment. Beyond this point the side walls are designed as ordinary retaining walls with spread footings and to act as cantilevers.

The side walls on the west abutment are 37 ft. in length and designed as ordinary retaining walls, the same as the portion of the side walls of the east abutment mentioned above.

The roadway of the bridge, which is of reinforced-concrete slab and floor beam construction, is supported on spandrel girders supported by columns 24 × 24 ins., spaced 15 ft. c. to c., resting upon the main arch ribs. The roadway on the approach spans is supported in a similar manner except the span is 21 ft. and the columns, which are 24 × 36 ins. extend to the rock below, the greatest length of the columns of the approach

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spans being 39 ft. and on the main span 29 ft. in length.

The sidewalks, which are reinforced, have a uniform thickness of 6 ins., with a slope of ¼ in. to the foot to provide drainage, are 10 ft. in width and are supported on beams acting as cantilevers spaced 7 ft. 6 ins. on the main span and 7 ft. on the approach spans.

Substantial concrete railing posts are provided on both the approaches and the main span, having the same spacing as the columns. Between these railing posts will be placed, under a subsequent contract, an iron bridge railing of appropriate design.

The bridge is lighted by four ornamental lamps placed on the curb lines opposite each main pier.

Reinforcement.

An efficient, economical and practical type of reinforcement for the main arch ribs was found more difficult to design, without infringement upon patent rights, than the arch itself. After considerable study the effort was abandoned and fabricated units or steel skeleton were shown on the plans, the contractor having the privilege of substituting any other approved form of reinforcement. On all other parts of the bridge the plans simply show the spacing and the sectional area except the abutments, where sizes and type of reinforcement is given. For reinforcement having shear members the contractor was permitted to make his selection from either the Kahn or Monolith bar for beams and slabs and the Cummings Loop Truss for beams only. Plans submitted by the contractor were approved for the Monolith bar, manufactured by the Monolith Steel Co. of this city and this type of reinforcement was used for the entire work on the bridge. The reinforcement is open hearth medium steel complying with the requirements recommended by the American Railway Engineering and Maintenance of Way Association.

The reinforcement for the main arch ribs consists of eight 1½-in. grooved bars, arranged in four pairs, each pair connected with ½-in. lacing bars, clamped into the grooves on the 1½-in. bars, and spaced about one foot apart, making a latticed girder effect, placed vertically and curved to fit the arch rib. The top and bottom bars were kept about four inches from the upper and lower surfaces of the concrete. The latticed girders were placed in pairs on each side of the rib, then transversely across the upper and lower bars of the latticed girders were placed stapled bars of the length sufficient to include the outside girders. The staples were then clamped around the longitudinal bars of the girder, so as to hold them accurately in their place, forming a box girder effect and acting as lateral stiffeners to the rib. All of the reinforcement was set in place and wired to the forms before concreting. The longitudinal bars of the latticed girders were made long enough to lap past each other in the key a sufficient distance to be U-bolted together, strong enough to develop the strength of the bars. After the various sections of the rib were cast, the U-bolts were securely tightened up and the keys concreted, the idea being to avoid initial stresses in the steel coming from the settlement of the forms on account of the load of the ribs. The strut reinforcement which was made in two pieces of latticed girder frames, similar to that of the ribs, was stapled to the longitudinal bars in the main ribs, the struts being placed at panel points on the bridge, the main bars being 1½-in. bars. The pieces were lapped past each other in the middle of the struts and U-bolted after concreting and keying the ribs strong enough to develop the bars. The struts were then concreted.

Where the column bases joined the ribs, shear reinforcement was placed in the ribs to take care of the secondary stresses owing to the concentrated load of the columns, and bars passed from the rib into the column base to carry the component of the column load passed along the rib axis. The column reinforcement is 1¼-in. vertical bars, stapled at 9-in. intervals and clamped around the hooped bands, which were 1¼-in. rounds.

The spandrel girders which were built above each arch rib, spanning from column to column on 15-ft. centers, were reinforced with five 1½-in. bars laid horizontally and two 1½-in. bars curved to fit the soffit of the arch. Top reinforcement was placed over the columns, although the spandrel girders were designed as simply supported.

The floor beams were supported by spandrel girders, having a span of 15 ft. c. to c. crosswise of the bridge. The floor beams were reinforced with four 1¼ bars and one 1-in. bar grooved as before, negative reinforcement being placed over the center column.

The sidewalk brackets extend out from the spandrel girders, their reinforcement being two 1¼-in. and one 1-in. bar grooved as before, placed on the top of the cantilever, extending back into the floor beams a sufficient distance to develop the bars.

The reinforcement in the roadway floor slabs is ⅝-in. grooved bars, spaced 6 ins. apart c. to c. on a span of 7 ft. 6 in.s c. to c. between the floor beams in a slab of minimum thickness of 8½ ins.

The reinforcement for the sidewalk slab is ⅝-in. grooved bars, placed 6 ins. c. to c. i... slab of 7 ft. 6 ins. span, between sidewal... ets. All the reinforcement for the flo... was set in place and wired to the form... concreting. Negative reinforcement w... in the floor slabs and sidewalk slabs o... supports, as if they had been designed to ... tinuously. Sufficient steel was placed in t... to take care of the bending moments as i... supported. The diagonal shear bar... clamped into the grooved longitudinal b... spaced as needed for shear in both gird... slabs. The total area of the shear bars ... equal to the total area of the grooved ba...

Round bars were used in the piers at t... of the main span near the surface of th... crete, to prevent cracking of the thin walls. The reinforcement was ⅜-in. round rods spa... 24 ins. apart and wired in place.

The floor construction was the same f... the approach as for the main span. The reinforcement for the approach arches consisted o... two 1½-in. and one 1-in. bars laid horizontally and two 1½-in. and one 1-in. bars following the soffit of the arches, only sufficient reinforcement being used to carry the live load, thus avoiding unequal thrust on the arches from moving live load.

Parts of the wing walls were designed as cantilever retaining walls where these were economical. Where the wing walls are high enough to make it less expensive to build vertical curtain walls and floor slabs for the roadway, the reinforcement was only sufficient to prevent possible cracking and was similar to that in the main piers. Grooved bars were used for both vertical walls and retaining walls. Stapled bars were used in the retaining walls for verticals, the staples being clamped around the horizontal bars, thus forming a frame tied together and not easily displaced by pouring of concrete.

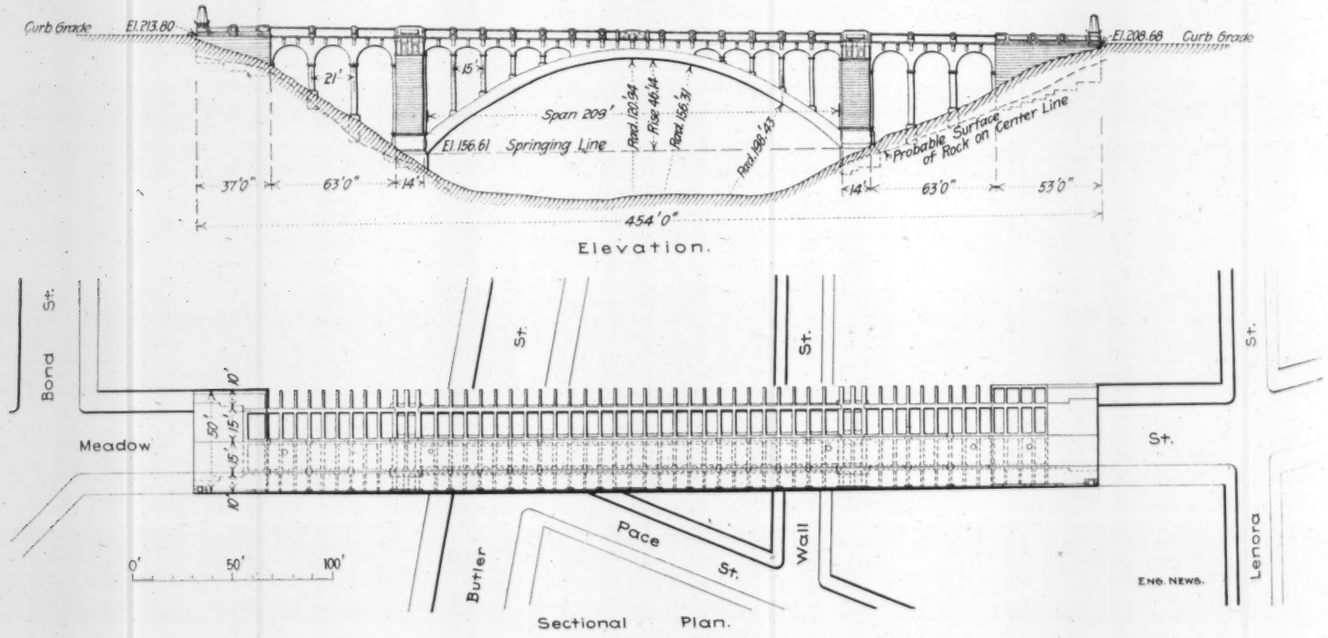


FIG. 2. GENERAL LAYOUT OF THE MEADOW ST. BRIDGE.

TABLE SHOWING PERCENTAGE OF STEEL USED IN DIFFERENT PARTS OF THE BRIDGE.

Part of bridge.	Size of beam.	Per-centage.
Floor slab	Depth 7½ ins.	1.14
Sidewalk slab	Depth, 6 ins.	1.6
Floor beams (T beams)	For T beam = 60×20 ins.	1.52
	Web = 24×13½ ins.	1.02
Spandrel girders	24×38 ins.	1.2
Main arch ribs (outside)	5 ft. × 3 ft. 9 ins.	1.11
Main arch ribs (center)	5×5 ft.	1.05
Approach arches	24×22 ins.	1.04

All depths are given from top of bea... to center of steel.

Laboratory tests were made to determi... the tensile strength of the steel and the e... ency of the connection between the tension and shear members. The results of these tests a... tabulated on the following page.

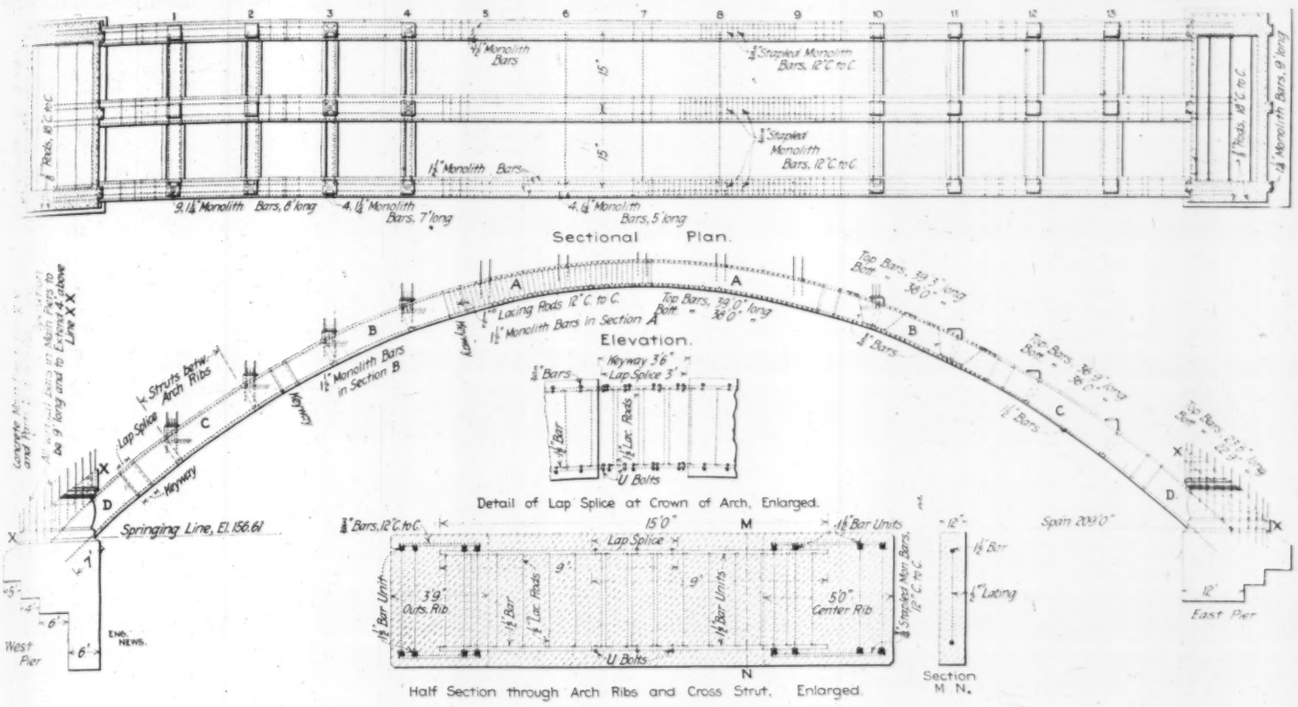


FIG. 3. DETAIL OF THE 209-FT. MAIN ARCH.

TENSILE TEST.

Test No.	Size of bar, ins.	Elastic limit, lbs. per sq. in.	Tensile strength, lbs. per sq. in.	Elongation per cent. in 8 ins.
1	1⅛	35,600	56,660	32.5
2	1¼	38,660	60,050	28.7

EFFICIENCY OF JOINT.

Size of bar, ins.	Size of loop, ins.	Breaking load, lbs.	Location of break.	Effect on joint.
⅝	3/16	3,600	Body.	None.
⅝	3/16	3,750	Body.	None.
¾	1/4	6,200	Body.	None.
¾	1/4	6,300	Body.	None.
1	3/8	13,800	Body.	None.
1	3/8	13,420	Body.	None.
1¼	7/16	21,150	Body.	Slipped 1 in. on one side
1¼	7/16	20,100	Body.	None.
1½	1/2	21,850	Shoulder.	None.*
1½	1/2	22,650	Body.	None.

*This loop sheared off on shoulder due to binding.

NOTE: Bars held in machine at an angle of 45° to the horizontal. Tension exerted vertically, bringing the line of action at an angle of 45° to the axis of the bar.

The specifications for cement were drawn in accordance with the standards prescribed for this material by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers. The main arch ribs, spandrel columns, spandrel arches, approach arches, floor system, parapets and railing posts are made of concrete, mixed in the proportions of 1:2:4. The concrete for the main piers, approach columns and abutments is mixed in the proportion of 1:2½:5. Broken stone, evenly graded from ¼-in. to 2½ ins. in diameter, is specified for the main arch ribs and gravel ranging in size from ¼-in. to 1½ ins. is required for all other construction.

Arrangements were made at the cement mill for grinding, and storing in a separate bin, lots of 3,000 bbls. After the filling of the bin it is sealed by a representative of the city and no cement is removed except in the presence of a representative of the city. By this method it is possible to have an ample supply of cement at all times from which to draw which has passed the 28-day test. The broken stone used in the concrete and for the main arch ribs is a hard limestone. The sand and gravel are taken from the Allegheny River, all of which is furnished by local dealers.

Foundations.

Previous to undertaking the design of this bridge test pits were excavated sufficient in number for a proper determination of the exact location of the rock surface. As anticipated from surface indications rock was found at a comparatively slight depth below the surface of the ground. It was therefore apparent that good foundations could be obtained at slight cost.

Two main piers are founded upon an indurated clay formation, similar to that used in the manufacture of bricks. This rock is quite hard, but when exposed it disintegrates rapidly. The footing courses of the piers were carried to a sufficient depth below the surface of the ground to prevent erosion of the underlying rock. The vertical pressure per square foot allowed was 8,000 lbs., which, from our experience, is about one-half the load this material is capable of sustaining without settlement. At the east abutment and at a much higher elevation a hard blue sandstone was found which is locally known as "blue stone." This stone is used quite extensively for building purposes, but after exposure to the elements it eventually becomes laminated and care was taken to prevent damage from this source. The west abutment is built upon a shale formation characteristic of this vicinity. The vertical pressure per square foot on the abutment foundations is about 2,000 lbs., which is not excessive.

Design.

Realizing that the appropriation was small for this work the strictest economy in concrete was necessary in its design to bring the cost of the bridge within the appropriation. Before proceeding with the design of the bridge several of the well known arch formulas were investigated and it was decided that Merriman and Jacoby's elastic arch theory was preferable on account of its accuracy, ease of application, and being well adapted to meet the requirements of the problem at hand.

The main span is a five-centered arch approaching very closely to a parabola. The spandrel girders are designed to act as beams, the object being to provide for expansion at the main piers. The spandrel girders were given the appearance of arches for esthetic reasons. On the approach spans the arches are designed for arch action under the dead load and to act as cantilevers under the live load. The temperature stresses were calculated, assuming a temperature of 70° F. during construction and a variation between a rise of 20° and a fall of 60°, using the for-

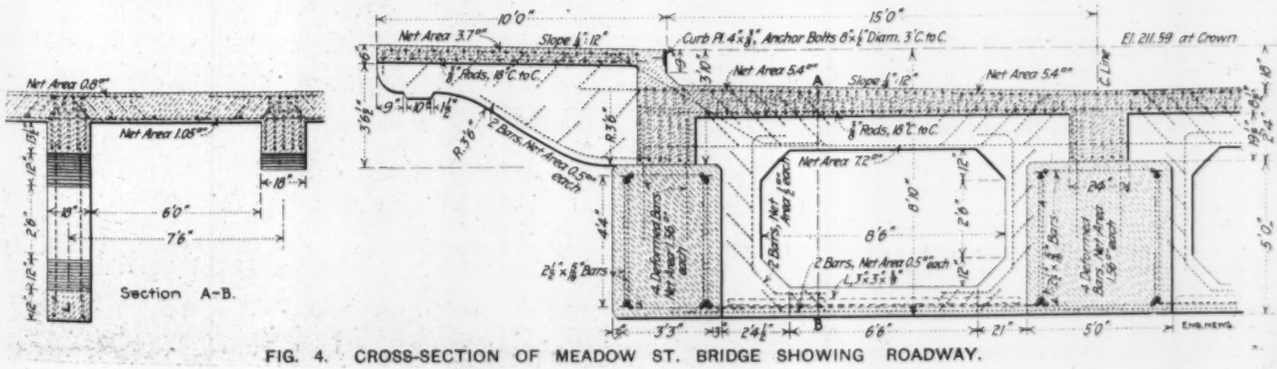

Section A-B.
El. 211.59 at Crown
Curb Pl. 4"x⅜" Anchor Bolts 8"=⅝" Diam. 3'C. to C.
⅝" Rods, 18"C. to C.
2 Bars, Net Area 0.5" each
4 Deformed Bars, Net Area .56" each
2½"x⅝" Bars
2 Bars, Net Area 0.5" each
L 3"x3"x⅜"
END NEWS

FIG. 4. CROSS-SECTION OF MEADOW ST. BRIDGE SHOWING ROADWAY.
(Reinforcement given only in general sizes.)

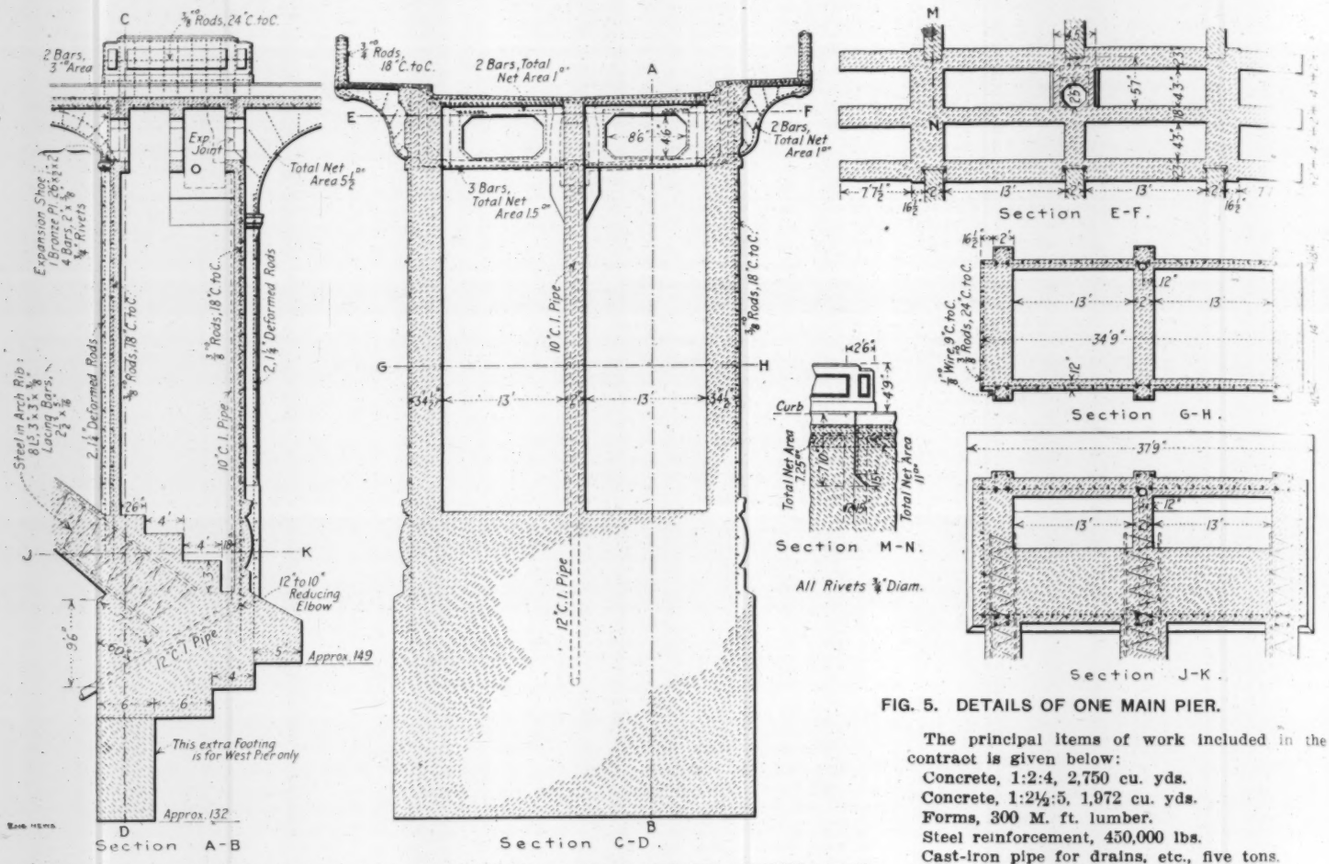


FIG. 5. DETAILS OF ONE MAIN PIER.

mula for the determination of stresses taken from the general arch theory as given by Merriman. Expansion joints are provided for the roadway construction at the main piers and abutments.

The line of pressure in the main arch ribs coincides very closely with the axis line, slight variations being made for the purpose of equalizing the compression stresses on each side of the arch. The main arch ribs were designed irrespective of the reinforcement, the reinforcement being added for the purpose of obtaining a more uniform distribution of the loads, to reduce the stresses and prevent cracking of the concrete.

The following assumptions for loading were made:

DEAD LOAD.—Concrete, including reinforcement, 150 lbs. per cu. ft.; asphalt pavement, including 6-in. concrete foundation, filling of gravel under the pavement and street car track construction complete, 140 lbs. per cu. ft.

LIVE LOAD.—A street car, weighing 35 tons, was used in the design of that portion of the roadway covered by tracks. A uniform load of 100 lbs. per sq. ft. was used over the balance of the roadway and 60 lbs. per sq. ft. on the sidewalks.

The working stresses used in designing the bridge were as follows:

TENSION.—Steel in floor slabs and main arch ribs, 12,000 lbs. per sq. in.; steel in beams and girders, 15,000 lbs. per sq. in.

COMPRESSION.—Concrete for local members 600 lbs. per sq. in.; concrete for main arch ribs, 500 lbs. per sq. in.

MODULUS OF ELASTICITY.—Steel, 29,000,000; concrete, local members, 2,000,000; concrete, main members, 2,500,000.

The formula used for the design of the reinforced-concrete beams, slabs and girders was taken from Turneaure and Maurer's treatise on reinforced concrete, the formula being based on Professor Talbot's parabolic theory of stress deformation.

The contract plans for this bridge were completed in January, 1910, the work advertised shortly thereafter and a contract for building the bridge was awarded Feb. 7, 1910, to the Friday Contracting Co., of Pittsburg, Pa.

The price bid, $64,326, is a lump sum for the furnishing of all materials, plant, tools and labor to build the bridge complete, except the paving of the roadway, the iron bridge railing and the ornamental lamps on the pylons and the main piers, which work will be done under subsequent contracts.

The principal items of work included in the contract is given below:

Concrete, 1:2:4, 2,750 cu. yds.
Concrete, 1:2½:5, 1,972 cu. yds.
Forms, 300 M. ft. lumber.
Steel reinforcement, 450,000 lbs.
Cast-iron pipe for drains, etc., five tons.

Contractors' Plant.

Immediately after the award of the contract the contractors started to install their plant and other equipment necessary to carry on the work. A traveling Lidgerwood cableway, having a span of about 670 ft. was set up on the line of the bridge, for handling the materials. The head tower, which is 64 ft. high, was placed at the

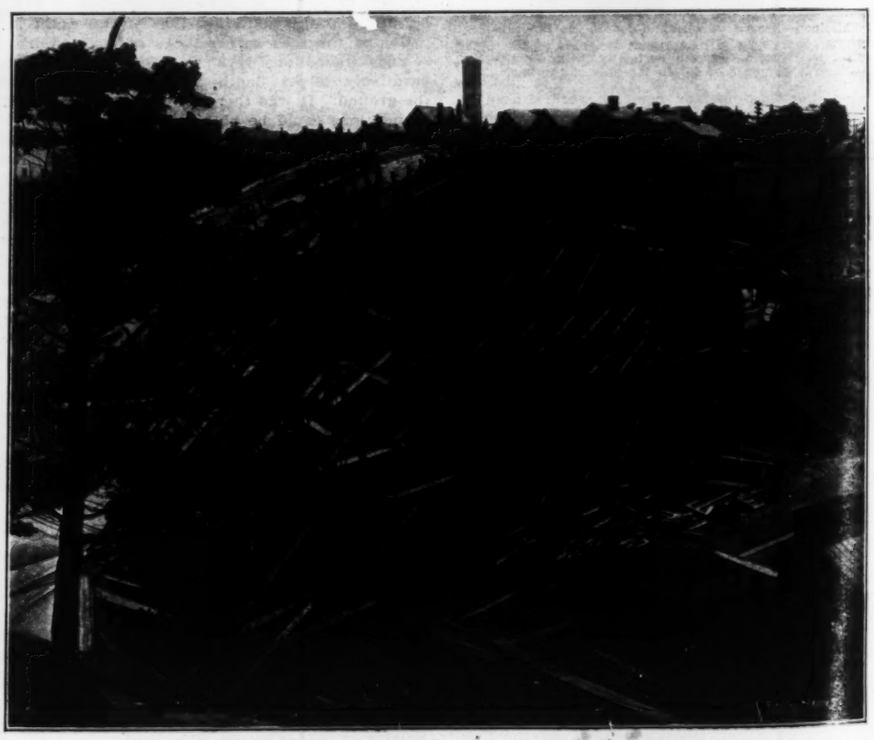


FIG. 6. VIEW OF BRIDGE DURING CONSTRUCTION.

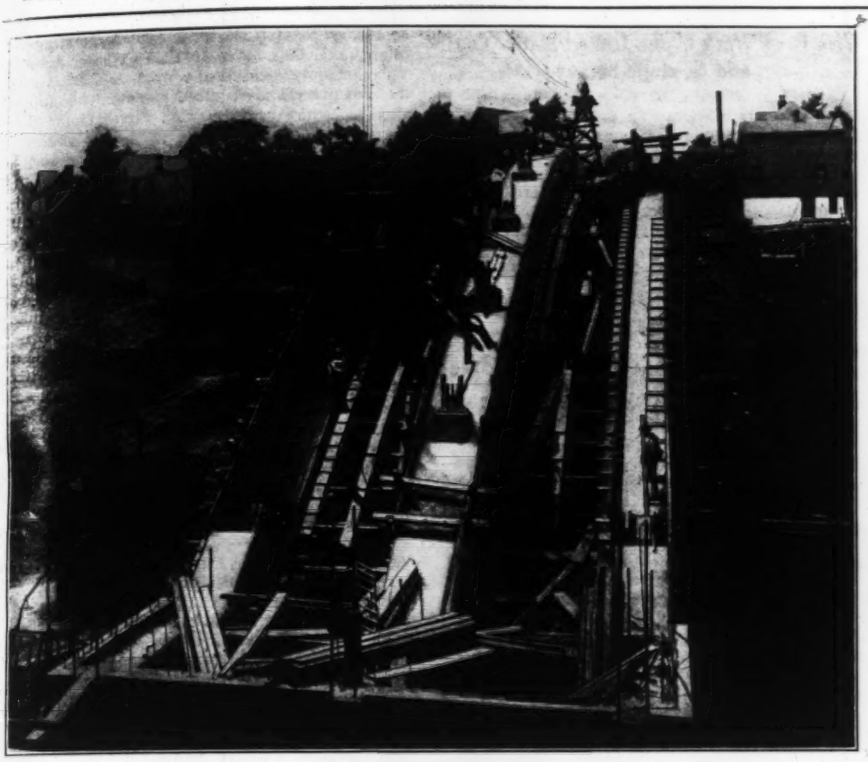


FIG. 7. DEPOSITING CONCRETE IN THE ARCH RIBS.

west end of the bridge and the tail tower at the east end of the bridge. Steam is furnished for the operation of this cableway from a horizontal fire tube boiler having a capacity of 50 HP.

A 40-cu. ft. concrete mixer was placed at the west end of the bridge upon the hillside in such a manner that the hopper was on a level with the street surface, making easy the feeding of the cement and aggregate. Steam was furnished for the operation of this mixer from a horizontal fire tube boiler, having a capacity of 30 HP., which also carried steam for the operation of the air compressor. The concrete was carried in a controllable bottom dumping bucket. The cement, sand, gravel and broken stone was all delivered by wagons at the west end of the bridge. In the valley the contractors had a small shop equipped with a power-driven band saw, where the forms for the concrete was made. The contractors also erected a field office, storage house and other smaller buildings, as required upon work of this nature.

Falsework.

The falsework for the main arch ribs was supported on a pile foundation, the piles having an average length of about 20 ft. and driven to refusal. There was eight piles in each bent, two on the center of each rib and one about 10 ft. distant at each side. On top of these piles was placed 10 × 10-in. caps which support the uprights. The longitudinal spacing of the bents was 15 ft. c. to c. At the level of the springing line of the arch screw jacks were placed under each post in order to adjust the centering to the proper height and for lowering when centers were removed.

The pile bents were braced longitudinally with six lines of 2 × 12-in. and 3 × 12-in. braces, the vertical spacing varying from 9 to 13 ft. and the number of lines diminishing toward the springing line of the arch, the 3 × 12-in. braces being placed on a level with the haunches. The diagonal bracing consisted of 2 × 10-in. timbers for the lower bents and 2 × 10-in. timbers for the upper, all securely bolted or spliced to the uprights. The top of each bent under the arch was capped with an 8 × 10-in. timber running transversely, on which was supported seven lines of 4 × 12-in. stringers, there being three lines under the center rib and two lines under the outside ribs. These stringers are cut to conform to the curve of the arch. Resting on these were 3 × 4-in. joists running transversely and spaced 12 ins. c. to c. The lagging which formed the soffit mold of the arch ribs consisted of 2-in. dressed plank, laid lengthwise and secured to the 3 × 4-in. joists. The side forms of the arch were 2-in. dressed plank laid horizontally and secured by 4 × 4-in. joists spaced 2 ft. on the centers with 4 × 6-in. pieces across the top and bottom, notched into them, and secured by wedges. The center rib was poured first, after which the side forms of this rib were moved over and used in a similar manner for the side ribs.

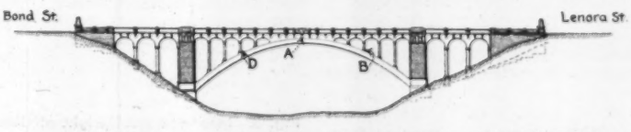


TABLE SHOWING CHANGES IN ELEVATIONS DURING CONSTRUCTION.

	A.			B.			D.		
	W.	C.	E.	W.	C.	E.	W.	C.	E.
Settlement of falsework under weight of arch rib sections	−0.097	−0.120	−0.096	−0.040	−0.043	−0.041	−0.041	−0.046	−0.045
Deflection of arch ribs previous to loading, centers removed	−0.019	−0.011	−0.038	−0.004	−0.005	0.000	−0.009	+0.002	+0.005
Deflection of arch ribs. Work completed	−0.146	−0.147	−0.148	−0.117	−0.120	−0.120	−0.071	−0.071	−0.072
Total deflections	−0.262	−0.278	−0.282	−0.161	−0.168	−0.161	−0.121	−0.115	−0.112

A = Crown of Arch.
B = ¼ Point of Arch Lenora St. end of bridge.
D = ¼ Point of Arch Bond St. end of bridge.
Settlement indicated by −.
W = West Rib.
C = Center Rib.
E = East Rib.
Rise indicated by +.

FIG. 9. DIAGRAM AND TABULATION OF DEFLECTIONS ON MEADOW ST. BRIDGE.

Construction.

The excavation for the abutments was started on March 4, 1910, following which came the excavation for the main piers. Concreting was started April 7, 1910, on the abutment at the Bond St. end of the bridge. This was followed in rapid succession by the foundations for the main piers up to and including skewbacks for the main span and the north abutment. Meanwhile the piles were driven to support the falsework of the main spans and this falsework was being erected while the main piers were being concreted. Forms were built for the first section of the main arch ribs and a section of the main piers as soon as sufficient falsework was erected. The first sections of the arch ribs was concreted monolithic with the main piers with the exception of the ornamental panel, which had been concreted previously.

The main piers were then built in about 15-ft. sections, each day's work being stopped at a coursing groove. This was done to avoid the line of demarcation that always comes on flat surfaces between day's work. By the time the main piers with their portions of roadway were finished the falsework and forms for the middle rib were complete. The rib reinforcement was then placed and concreting of the middle rib for the main span started.

Concreting the main span was done in four operations, as shown in the accompanying sketch (Fig. 8). Operation No. 1 involved the main ribs, No. 2 the keys of the arch ribs, No. 3 the spandrel columns and No. 4 the floor system on top of the columns. The method of concreting the two outside ribs was similar to the center rib, as described below. The two sections nearest the crown were concreted first, followed by the section nearest the springing and the haunches respectively. This was followed immediately by U-bolting the sections of reinforcement in the keys and concreting the keys, as described elsewhere in the paper. Sections were about 30 ft. long and keys were placed between columns, the keys being 3 ft. 6 ins. wide. Concreting the keys was accomplished in one day for each arch rib. Similar keys on opposite ends of the span were placed at the same time and the column bases were cast with the sections. Struts 12 ins. square were built in the keys between the sections.

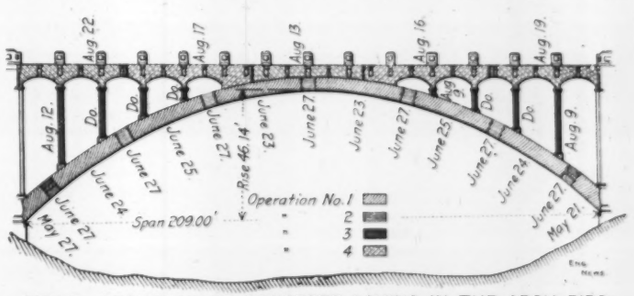


FIG. 8. SEQUENCE OF CONCRETE LAYING IN THE ARCH RIBS, MEADOW ST. BRIDGE.

The floor system is of beam and slab construction, spandrel girders supporting floor beams at half panel intervals and the floor roadway slab and sidewalk resting on them. Reinforcement for the floor system was placed in the usual way. Concreting was stopped at the middle of a span in every case. Concreting of the approach spans was next undertaken. The columns were done first and the approach arches and floor system were concreted in one operation, each day's work being stopped as before at the middle of the span. Before concreting, all forms were oiled to prevent sticking of the concrete. The concrete was also carefully

spaded, while the concrete was wet before initial set had taken place. Forms were removed from the sides of all work as soon as practicable after concreting and the surface rubbed off with emery stones and water. A grout, proportioned one to two, was then put on with brushes and rubbed into the concrete with wooden trowels. This method of finishing has thus far proved very satisfactory, the work having a uniform gray color and a pleasing appearance to the eye.

Forms underneath beams and slabs were left on ten days for a good set before being removed and the work was so smooth that little rubbing was necessary in this case. It was found that after concrete became 48 hours old the rubbing down was very hard to do, but before this it was comparatively easy of accomplishment. Forms for the lower side of the main arch ribs were left in place 20 days before lowering the centering. This was done on July 19 in about 30 mins. time by operating screw jacks mentioned above.

Operations Nos. 3 and 4 were done after the arch ribs had been completed and the ribs stood the partial loading of the spandrel columns and floor system without any perceptible changes. The stresses in the ribs then exceeded anything that is likely to occur at any future time.

Accurate levels were taken on the main ribs at the points shown on the sketch in Fig. 9.

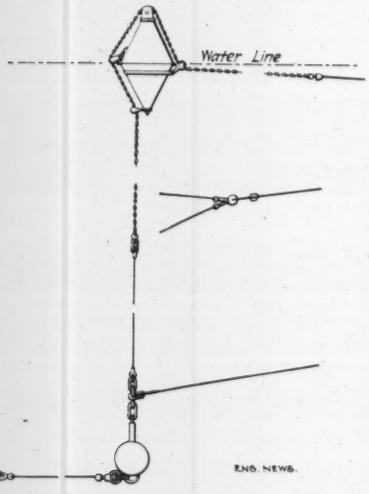


Fig. 2. End Upright of Coast Survey Drag.
(Lower half of sketch approximately twice the scale of buoy.)

These levels showed that the settlement of the centering was enough to justify careful attention in planning the method of concreting the ribs. The ribs themselves did not show any appreciable change under their own weight, showing that there will not be much danger from application of the whole dead load on the bridge.

In the preparation of this paper, credit is due Mr. Willis Whited, Engineer of Bridges, and Mr. John A. Ferguson, Assistant Engineer, for assistance rendered and suggestions given.

Wire Drag Work of the United States Coast and Geodetic Survey.

Some four years ago* there was described in these columns a wire drag or sweep, for use in locating obstructions to navigation in harbors and channels, which was then in use on the Lake Survey by the U. S. Engineer Corps. This drag was invented and was described by Mr. Francis C. Shenehon, M. Am. Soc. C. E., then Assistant U. S. Engineer, and now Dean of the Engineering College at the University of Minnesota. A 1,200 ft. drag of this type is shown in Fig. 1, which we re-

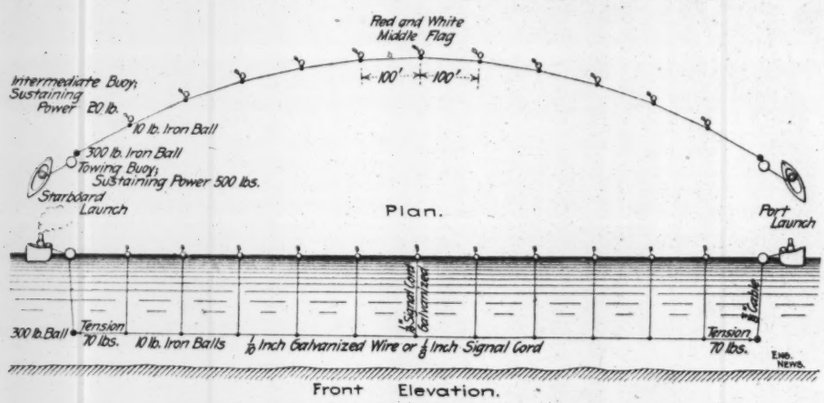


FIG. 1. A 1,200-FT. SWEEP OR DRAG USED ON THE LAKE SURVEYS, 1903.
(Reproduced from Eng. News, April 26, 1906.)

produce from the issue of April 26, 1906. Mention was made by Mr. Shenehon of a drag adopted by the United States Coast and Geodetic Survey modeled after his design. This drag, then used in lengths of 480 and 1,000-ft., was practically identical in design with the Lake Survey, 1200-ft. drag as shown in the illustration. Since 1902 the Coast Survey has had a party continuously in the field making surveys with this apparatus, and the original wire drag has undergone many improvements and modifications to adapt it to a great variety of conditions.

The first season's work of the Coast Survey was under Assistant D. B. Wainwright, but since 1903 all the work of the wire drag party has been under the direction of Assistant N. H. Heck, Assoc. M. Am. Soc. C. E., to whom we are indebted for the information contained in this article.

The wire drag, in principle, is not new and some form of drag or sweep has long been in use both in this country and in France for finding the exact location of previously known obstructions or for verifying channel depths after dredging. It is however to the United States Coast Survey that credit should be given for first making extended surveys with the wire drag in tidal waters.

It is obvious that the conditions met with in tidal waters, especially those of Maine, are vastly different from the conditions on the Great Lakes where almost all the previous experience with wire drags had been obtained. The first and most important element of difficulty is the tide. On the coast of Maine the range is sometimes as great as 16-ft. from high to low water, which of course occurs within about six hours.

The first drag was designed to sweep to a depth of 6 fathoms (36 ft.) and no other adjustment for depth was provided than that which could be obtained by increasing or decreasing the towing force, thus changing the resistance of the uprights and their inclination from the vertical; a range of about 8 ft. in depth could thus be obtained with towing pulls varying from 100 to 200 lbs. This not only gave insufficient range but did not permit the full power of the launches to be developed and hence progress was slow.

The first improvement therefore was to make the uprights adjustable so that they could be changed as the tide changed. This was accomplished by making the uprights in sections so that hookups could be obtained to the nearest foot. To change the uprights, however, it was necessary to stop the progress of the d[rag] and often take in and reset the major par[t] of it. This not only delayed the work but ofte[n] broke its continuity and required more or less [re]ca-tion to cover the area with certainty.

Another difficulty met with in this fi[eld] was the fact that the lengths of the [up]rights were required to be so much greater t[han] the depth to be verified that in setting out t[he] drag the weights were often grounded and grea[t] difficulty experienced in getting the drag und[er] way.

While these difficulties had to do wi[th] the drag itself, there is still another which [in]troduced delay and thus added greatly to t[he] cost of the work. This is the lobster catching [in]dustry. A lobster trap or as it is locally kn[own] "a pot" is nothing more than a wooden cag[e] anchored to the bottom by a weight, and w[ith] a hauling line attached to a wooden float. Th[ese] of course become entangled with the bottom [wi]re and seriously interfere with the work. To [o]vercome this difficulty, areas are now mapped [o]ut and posted on the charts in a public place [w]ith a warning to all lobstermen, to remove [th]eir traps from the designated area. The area [it]self is marked out by can or spar buoys. This prevents claims being made to the government for damage to traps and is more or less effectual in clearing the prescribed areas of traps.

While we will not attempt to describe the various steps of improvement made in the wire drag we believe that a short description of the present improved drag will be of interest to engineers, not only as the solution of a particular engineering problem but because the drag itself has become an almost indispensible instrument in hydrographic surveying.

The drag is made in lengths of 1,200 and 2,000 ft. for two launches, 4,000 for three launches, and 6,000, 8,400 and 10,000 ft. for four launches. The bottom wire, i. e. the horizontal member, is made up in each case of sections 50 ft. long. Instead of placing buoys at each 100 ft. length as previously used (see Fig. 1), small wooden floats are attached directly to the ground wire, specially designed can buoys with wire uprights without uprights, at all intermediate 50-ft. sections between points 150 ft. apart on the 1,200 ft. drag and so on by increasing units up to 350 ft. for the 8,400 ft. drag. At these points and 20-lb. weights are attached. At the ends of the drag and at intermediate towing points, large can buoys with uprights and 165-lb. weights are attached.

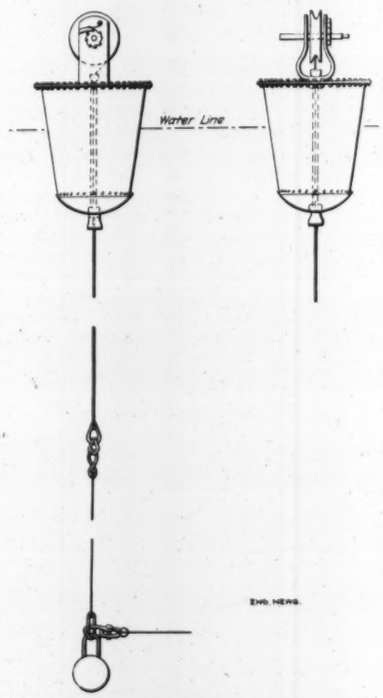


Fig. 3. Intermediate Upright of Coast Survey Drag.

*See Eng. News, April 26, 1906, pp. 462-464.

The large towing buoy is shown in Fig. 2. It is conical in shape and made of No. 18 galvanized iron, riveted at all joints and soldered to prevent leaking. The upright attached to the bottom wire is adjustable by being made of galvanized iron chain which passes over the top of the buoy on a pulley and thence forms part of the towing line as is clearly shown in Fig. 2. The chain is graduated by painted links so that it may be set at any depth by turning the pulley wheel by means of a detachable crank. This may be done while the drag is proceeding ahead by running along side in a tender, the force required to lift the weight being much less than was formerly required to lift it when the drag was at rest, owing to the help given by the towline. When once set the pulley wheel is locked so that no change of pull on the towline can affect it.

The towline attachment to the large buoy and upright is shown in Figs. 2 and 5, and represents a vast improvement over the former method of towing from the bottom of the buoy only. (See Fig. 1). The additional length of upright now required because of the inclination from the vertical is so small that the drag may be set out in water only two feet deeper than the depth to be verified, without fouling on the bottom.

The small intermediate buoys are shown in Fig. 3. They are now made of the same material as the large buoys and have adjustable uprights of flexible woven wire cable which can be wound on a drum on the top of each buoy. These can be set at any depth from a tender run along side. They also make it possible to get clear of a shoal when once found by merely raising the bottom wire to clear the obstruction and going ahead after which the uprights are dropped again to their proper depths. This adds very greatly to the time saved in getting clear of shoals and saves many complications which formerly existed when it was necessary to reel in the whole drag to get clear. The increasing of the distance between buoys from 100 to 150 or 350 ft. also represents a distinct gain not only in outfit but in the resistance to be overcome in moving the drag. The small wooden floats at the 50 ft. intermediate points between the small buoy uprights serve chiefly to keep the wire from the bottom while the drag is at rest. When moving the tension in the bottom wire is probably sufficient to keep it from sagging.

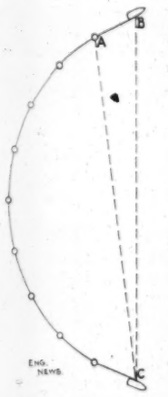


Fig. 4. Plan of Drag Showing Method of Control.

For towing the drag, gasoline launches or motor boats are used. These are obtained of private owners under contract for the season, and are divided into two classes, guiding launches and end launches. For a guiding launch, a boat of about 40 ft. length and 9 or 10 ft. beam with a good house is required. The power is ordinarily about 20 HP. In Maine where the work has been continuous for a number of seasons a specially adaptable type of boat has been developed. Such a boat shown in the accompanying cut was used during the present season. It is fitted with a wrought-iron reel driven by a 2½ HP. gasoline engine for taking up the drag. In a two launch drag all of the drag with the exception of one large upright is taken up on the reel of the guiding launch. This operation now requires but about a half an hour with the longest drag. Each guiding launch is equipped with a small power boat as a tender. This tender patrols back and forth across the drag while it is in motion keeping a constant lookout for any break or evidence of its being caught on bottom. The tender also makes the changes in uprights previously referred to without interrupting at all the progress of the drag.

The entire operation and control of the drag is accomplished from the guiding launch, which is equipped with a drafting table on which an especially prepared chart of the area being dragged is placed. The position of the drag is plotted

FIG. 5. TOWLINE ARRANGEMENT AT END BUOYS.

by first obtaining the position of the guiding launch by two sextant angles on shore signals and plotting by means of the three-arm protractor. The exact position of the drag is then determined by the solution of the triangle A B C of Fig. 4. The length of the tow-line A B being the base, the angles B and C are simultaneously obtained from the two launches and the distance A C determined, C being the guiding launch and A the large buoy at the farther end of the drag. This triangle is easily solved in a few seconds by an ordinary slide rule but to simplify the operation as far as possible a special form of circular slide rule was devised. With this distance and the angle between the buoy A and one of the shore signals, the position of far end of the drag is obtained.

The near buoy is easily located by an angle and the length of the towline. The angle B is signaled from the end launch by means of a wigwag system similar to that employed in the navy. The movements of the end launch are controlled by a signal system of four large colored balls on the roof of the guiding launch. By combinations of these it is possible to convey all ordinary orders to the end launch. Supplemented by the wigwag system mentioned before, it is possible to convey any information desired across the intervening space. The four-launch 10,000-ft. drag is operated from each end very much as two independent drags would be. In a three-launch drag the guiding launch is in the middle and the two ends are operated as two separate drags.

The guiding launch is in charge of one officer who does the plotting and takes one of the position angles. A second officer takes the other position angle and the buoy angles and a recorder keeps all notes. The crew consists of four men, two of whom operate the tender. The end launch is in charge of one officer who takes the necessary angles and has a crew of two men. When the drag is hung officers from both

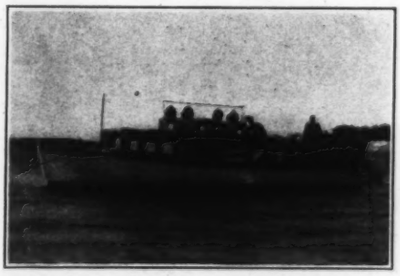


Fig. 6. Guiding Launch Used on Maine Coast.

launches make the soundings and take the location angles.

When a shoal is struck the drag will hang and the angle of the buoys will be such as to show very clearly the location of the obstruction. Soundings are then made and the exact location of least water obtained by sextant angles. The drag is then lifted over the obstruction as previously described, but before the vicinity is left the same shoal is dragged over at a slightly less depth than that obtained by soundings. This gives absolute assurance that the least water or the shoalest place has been found. The depth at which the wire is dragging may be tested at any time by dropping a specially designed lead line in front of its course and "feeling" for the wire as it passes. There is a very remarkable uniformity of depth throughout the drag.

To fully appreciate the usefulness of a wire drag survey one has only to consider the inadequacy of ordinary methods of hydrographic surveying by soundings. A skillful topographer may so select his points of elevation and depression that by a commanding position overlooking the whole, he may obtain a very accurate map of any land area. Not so with the hydrographer, however skillful he may be. The evidence of his sounding line is presumptive only and by its use he can form only a meager conception of the real character of the sea bottom. The most accurate method of soundings employed by the Coast Survey over extensive areas is to run parallel lines at intervals of 50 meters in either direction at right angles, thus forming a series of squares. On occasional instances diagonals to these squares are also sounded. On these lines the soundings are practically continuous and typical ones are placed on the charts. Yet within each of the triangles thus formed, there is an area of 625 sq. meters, the character of which is wholly unknown. On a rugged coast like that of Maine, experience has many times shown that pinnacle rocks, of much less area, may often rise from a depth of surrounding water of 15 or 20 fathoms to within a few feet of the mean low water level.

Nor is this a really typical example of sounding methods since the sounding lines are frequently run 100 meters apart and without diagonals. Under these conditions it is not strange that year after year dangerous shoals or reefs have been discovered where the charts have shown sufficient depth of water for the largest vessels.

There are many coasts, like those of the United States from New Jersey to Georgia where the bottom is so regular that the ordinary methods of hydrographic surveying are sufficient for all purposes. On rugged broken coasts like that of northern New England soundings may mean little or nothing and the wire drag is indispensable in making chart corrections. Although very different geologically, the coasts of Florida and Porto Rico are equally rugged with that of Maine, having as they do, many dangerous coral reefs and shoals. Here the wire drag has been employed for several successive winters with great success, especially in and about the harbor of Key West, Fla.

There is still another type of sea bottom where soundings are apt to be deceitful. This is on sandy or muddy bottom with occasional boulders. Such are the coasts of Massachusetts, Rhode Island, Connecticut and New York where the glacial drift of former times left many huge boulders far from the present shore line. There are believed to be many such boulders in Long Island Sound. Here also the wire drag has been usefully employed.

The cost of the wire drag work has been steadily reduced with the improvements mentioned so that it is now possible to cover an area of Maine coast at very nearly $100 a sq. mile whereas the cost originally ran as high as $250 a sq. mile. In all some 325 sq. miles have been covered. Although the wire drag has reached a high state of perfection, this has been accomplished without so complicating its construction but that the equipment may easily be made in any sea port of modest size on very short notice; an end which has been constantly kept in view.

THE FLUSHING OF THE MENOMONEE RIVER, at Milwaukee, Wis., is one of the subjects being considered by the commission appointed by the city to investigate the question of sewage disposal. This commission is composed of John W. Alvord, Geo. C. Whipple and H. P. Eddy, Mems. Am. Soc. C. E. The Milwaukee River and Kinnickinnic River (in Milwaukee) are now flushed with water pumped from the lake through connecting tunnels, but to apply this system to the Menomonee River would require a very large tunnel. The river flushing plants were described in our issue of Aug. 1, 1907.

Further Tests on the Effect of Electric Currents Upon Concrete and Steel.

By U. JAMES NICHOLAS.*

The object of this research, which was carried on in the Natural Philosophy School of the University of Melbourne by the aid of funds furnished by the Government of Victoria, Australia, was to make a further study of the effect of electric currents on reinforced concrete. Earlier work was carried on by the late A. A. Knudsen, published in the "Transactions of the American

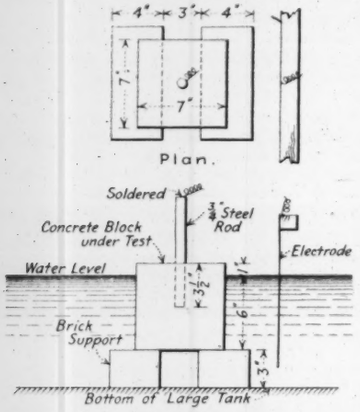


Fig. 1. Method of Testing Cubical Blocks Under Electric Current.

Institute of Electrical Engineers," Vol. 26, part 1, p. 231 (see Engineering News, March 21, 1907), and by U. James Nicholas at the Massachusetts Institute of Technology, and published in Engineering News for Dec. 24, 1908, p. 710. Tests at Washington University were noted in Engineering News, April 29, 1909, p. 458. The investigations here described have tended to show:

(1) That electrolytic corrosion of structural and reinforcing steel embedded in concrete takes place at the anode.

(2) That even neat cement is no protection against this corrosion.

(3) That the cathode is not affected by oxidation.

(4) That cement and concrete in brine will crack when carrying an electric current to or from embedded steel, and cannot, therefore, under these conditions, be regarded as an insulator in any sense.

(5) That the concrete conducts electrolytically and not as a metal.

(6) That as small a current as 0.1-amp. continuously flowing will accomplish the results indicated above.

(7) That the resistance of concrete is an inverse function of the percentage of sand.

The following questions have been investigated in the work now described:

(1) The effect of a constant potential of 10 volts, direct current.

(2) The effect of currents of considerably smaller amperage than those so far used.

(3) The effect of small currents on blocks of concrete, etc., when the steel was made the cathode.

(4) The effect of small currents on steel embedded in sandstone, basalt and brick, and

(5) The cause of the cracking of the concrete.

The tests were made on 34 blocks of concrete, sandstone, basalt and brick. Twenty-eight of these blocks were cubical in shape, 7 ins. square on each face, comprising sixteen concrete blocks, six sandstone blocks, three basalt blocks and three blocks of brick. The other six blocks were of the section shown in Fig. 2.

The concrete blocks were made of a standard Portland cement, which was thoroughly tested before use by the ordinary tests for tensile strength, fineness, etc. The sand used had the following granulometric composition:

Size of screen in meshes per inch.	Per cent. of sand remaining in screen.
On 10 × 10	1.3%
" 20 × 20	13.5%
" 30 × 30	14.4%
" 50 × 50	50.3%
Through 50 × 50	20.5%

The stone was basalt screenings broken to pass through a 1½-in. mesh. The specific gravity of the stone was 2.76, and its voids 52%.

All concrete was thoroughly mixed to a wet or mushy consistency and rammed in two layers each of 3½-in. thickness into wetted wooden molds until a little water flushed to the surface. A piece of ¾-in. diameter mild steel was inserted 3½ ins. into the center of the block, and the concrete was then allowed to set up under fresh water at least 50 days before testing.

The sandstone and basalt blocks were shaped up roughly to 7-in. cubes, and a 13/16-in. hole drilled 3½ ins. into the center of one side. A piece of ¾-in. diameter steel rod was grouted into this hole with 1:1 sand cement grout. The 7-in. cubes of brick were molded, pressed and burnt in a brick-works, being made in the same way as an ordinary machine-made brick. A piece of ¾-in. diameter mild steel rod was inserted 3½ ins. in the center of one side before burning.

All blocks were free from cracks before test.

Method of Carrying on Test.

The cubical blocks, 7 × 7 × 7 ins., were tested by placing them in two large galvanized iron tanks, which held a quantity of water, to which 3% of salt had been added. The water then contained as much salt as is present in sea-water.

The blocks were supported on bricks and immersed until their top surface was 1 in. above the level of the water. (See Fig. 1.) All these blocks were connected in parallel across 10 volts d. c.

In No. 1 tank, direct current at a constant potential of 10 volts was led to the blocks by a large galvanized iron anode partly immersed in the bath. The current then flowed through the water to the block, through the block to the piece of ¾-in. diameter mild steel inserted for 3½ ins. into its center, up through the steel, and away to the negative terminal. The steel rod thus formed the cathode, and the current flow was in the direction of "from concrete to steel."

Current measurements to each block were made daily except on Sundays. The deviation of current from the average shown in the tables varied from 10 to 40%. The sheet-iron anode was replaced as it became dissolved, and the water was changed once during the test. The results of this test are shown in Table I. for concrete blocks, and Table II. for blocks of stone and brick.

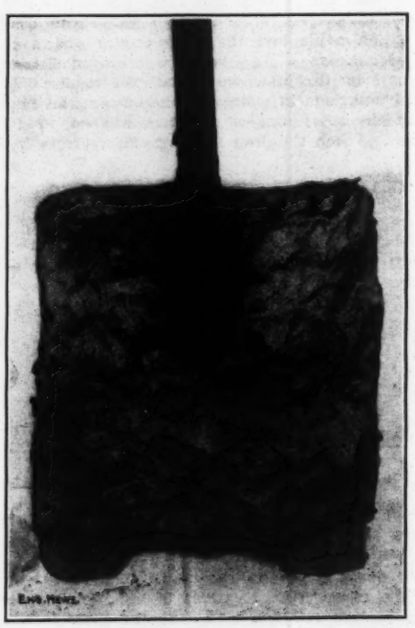


Fig. 3. View of Concrete Block No. 16 Split Open After Being Subjected to Current. Steel is Cathode.

(Note zone of darkly discolored cement around the cathode.)

In No. 2 tank, a direct current at a constant potential of 10 volts, was led to the block by the ¾-in. steel rod. It then flowed from the rod through the block out to the water and to the metal tank. The steel rod thus formed the anode, and the current flow was "from steel to concrete." Fig. 1 again shows the general arrangement for this test.

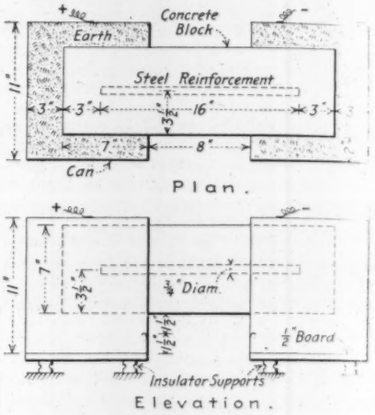


Fig. 2. Method of Testing Long Blocks.

Table III. shows result of this test on the concrete blocks, and Table IV. the result of this test on the stone and brick blocks.

The six long blocks were 7 × 7 ins. in cross-section, and 22 ins. long. They were reinforced by a piece of ¾-in. diameter mild steel, 16 ins. long, placed along the major axis of and in the center of the block and reaching to within 3 ins. of each end. (See Fig. 2.) The steel was then completely buried in concrete and did not emerge at any point. For test, each end of the block of concrete was buried 7 ins. into earth, which was held in a sheet-iron can. The earth used was a loamy garden soil. The cans were insulated from their supports so that a current led to the first can was compelled to flow through the earth to the end of the block of concrete, which was thus the positive end of the block, through the block to the steel, along the steel to the other end of the block, which was then the negative end, out through the block to the earth in the second can, and, finally, away by the second can. The direction of current was then, first, "from concrete to steel" at the positive end, and, second, "from steel to concrete" at the negative end.

The earth was kept moist by occasionally adding 100 c. c. of fresh water to replace evaporation losses.

The top surfaces of two of these blocks tested, viz., Nos. 4 and 9, were kept continually moist by pouring water on them; the water was prevented from escaping by a small dam built around the edges. Three ¾-in. holes were drilled 1½ ins. into the blocks to receive thermometers for testing the temperature of the interior of the blocks. The currents flowing, however, were not sufficient to appreciably raise the temperature above that of the surrounding air.

The other two long blocks tested, namely, Nos. 5 and 7, were not wetted on their top surface, and had no holes drilled in them for the reception of thermometers.

All the long blocks cracked as shown in Table V.

One 7-in. cubical concrete block was tested dry, the steel rod being the anode or positive terminal, and a piece of galvanized iron grouted on to the bottom surface of the block the cathode or negative terminal. This block was allowed to set up in air for 73 days, and, while quite dry, had so high an electrical resistance as to prevent any appreciable current flow, and the block was therefore unaffected. Five grams of fresh water poured on the block were sufficient to

*Care of Canadian Bank of Commerce, Seattle, Wash.

…der it quite conductive. (Table VI. shows the … of this test.)

…e 7-in. cubical concrete block was tested with …nating current at a constant potential of 47 …s. A small hole drilled into the block allowed …insertion of a thermometer, and it was found …t, with 47 volts and 0.2 amps., the internal …perature was as much as 10° C. above the …er in which the block was immersed. The …k did not crack after 188 days of test under these conditions. (Table VII. shows the result of this test.)

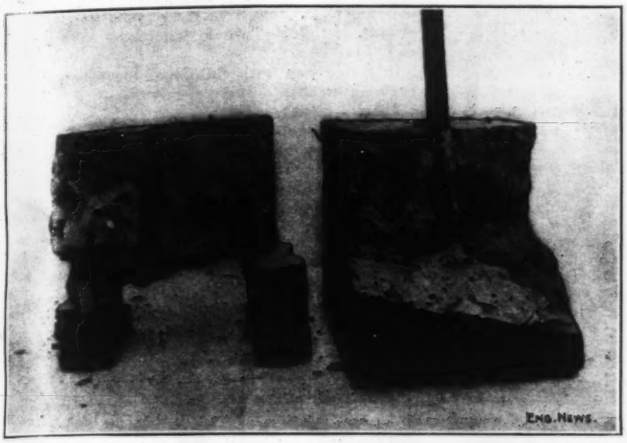


FIG. 4. VIEW OF CONCRETE BLOCK NO. 19 SPLIT OPEN AFTER BEING SUBJECTED TO CURRENT.

In order to ascertain the effect of a high temperature alone, with the electrolytic effect absent, the voltage to the above block was increased to 175 volts a. c. at the expiration of the above test. The temperature and current at once gradually rose, and in 27 mins. stood at 99° C. and 3 amps. respectively. The block then cracked; superheated vapors escaped from the crack; the current fell in 30 secs. to 0.1 amps. and remained at that value for 11 days. The internal temperature then was about 60° C. and the external 30° C. The crack did not open out during the 11 days, but remained a fine hair crack.

Discussion of Results.

Of five concrete blocks and two stone blocks in which the steel was cathode, no evidence of cracking appeared after 200 days of test. (See Tables I. and II.) In the blocks carrying the larger currents, gas escaped vigorously from the steel cathode and seemed to loosen and carry away particles of cement and sand in the immediate vicinity of the cathode. On the exterior of the blocks, an irregular, brittle, metallic coating was deposited from the anode. Fig. 3 shows the internal appearance of Block No. 16 so treated. The concrete in the immediate vicinity of the steel comprised a zone of dark-colored cement, indicating action by the gas, probably hydrogen, liberated at the cathode.

When the steel rod was the anode, however, all the concrete blocks cracked, including No. 19, which had been covered after drying with two coats of hot tar, and No. 23, which had been waterproofed with three alternate coats of hot alum solution and hot soapy water applied alternately every 24 hours. These cracks were similar in appearance to those noted in the former tests by the writer, and, if the current were maintained, gradually open out till about 1/16-in. wide. (See Fig. 4.) A universal percursor of the cracking was the appearance of three or four small drops of reddish rust-stained water, which slowly welled up through the concrete and gradually grew in size. The exterior surface of these drops became a thin film probably of iron oxide which seemed to greatly increase their surface tension. After 24 hours or so, these drops broke, and the crack shortly after appeared. The cracked blocks were easily pried open with a chisel, and showed marked evidence of rusting and pitting. The plane of the crack was through the axis of the steel.

With reference to the long blocks, an inspection of Fig. 5 will show the location of the cracks, which is noteworthy. At the positive end, where the direction of the current was "from concrete to steel," no cracks appeared. At the negative end, where the direction of current was "from steel to concrete," the cracks always appeared. The cracks extended one-half the length of the block, and passed through the axis of the steel.

The sandstone, basalt and brick blocks were tested to determine the effect of current on the natural stone, and fire-hardened brick, which did not owe their strength in any way to a process of crystallization as concrete does, thus determining whether de-hydration of the cement crystals by the electric current caused the cracking.

Two sandstone blocks with steel as anode, viz., Nos. 28 and 38, into which the steel had been firmly grouted for some time, cracked in 6 and 8 days with currents of 0.024 amps. and 0.066 amps. respectively. (See Fig. 8.) Two similar blocks viz., Nos. 37 and 41, were then drilled with a 13/16-in. hole, and instead of grouting the steel anode therein, a little mercury was poured into the hole, and the steel then inserted.

Neither of these blocks cracked with steel as anode, and currents of 0.021 amps. and 0.141 amps for 176 and 146 days respectively (see Table IV.).

The block of brick proved weaker than the concrete or stone, cracking in 9 days with steel as anode, and with an average current of 0.088 amps. (see Table IV. and Fig. 8).

The basalt block withstood an average current of 0.003 amps. for 200 days without cracking with steel as anode (see Table IV.). This was the only block with steel as anode which did not crack when the steel of course was grouted into its hole. The current, however, was considerably smaller than the other currents.

A number of blocks were made of concrete, stone, etc., which were not tested with current in any way. These were allowed to set up in water for 250 days for comparison with the blocks tested with current. Fig. 7 shows one of these blocks broken open. It resisted strongly a number of strokes from a heavy hammer and cold chisel before breaking.

Theories of Cause of Cracking.

Two theories of the cause of the cracking will be now discussed. According to the tests of Quincke, which have been discussed by Helmholtz under the title of Electric Boundary-Layers in the Physical Memoirs of the Physical Society of London, Vol. I., Part 1, 1888, it appears that an actual bodily transfer of electrolyte takes place under the action of electric currents. In these investigations, Quincke employed narrow capillary tubes, and porous clay partitions, in which the mean diameters of the pores were 1/13 to 1/40 mm. The direction of motion of the electrolyte was towards anode or cathode according to the electrolyte used. This transference caused a rise in hydrostatic pressure at the anode or cathode by heaping up the electrolyte as it were. If, now, we consider the voids in a mass of concrete to be composed of a series of very fine capillary tubes extending radially from the steel, it is conceivable that an endosmotic pressure at the anode could be created by a bodily transfer of electrolyte through these capillary tubes, and result in a rise of hydrostatic pressure at the anode. Unfortunately, time would not permit of arranging a test to determine by experiment the direction of flow of the 3% sodium chloride electrolyte used.

It may be significant, however, that the experiments on concrete seem to demonstrate that the

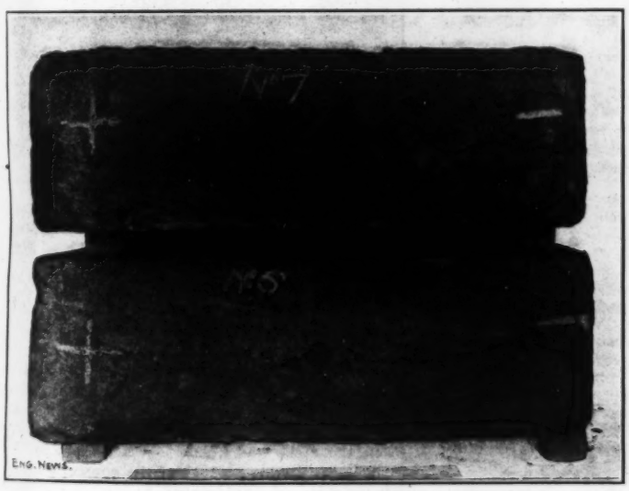


Fig. 5.
[Note that the cracks appear only at the negative end of the blocks.]

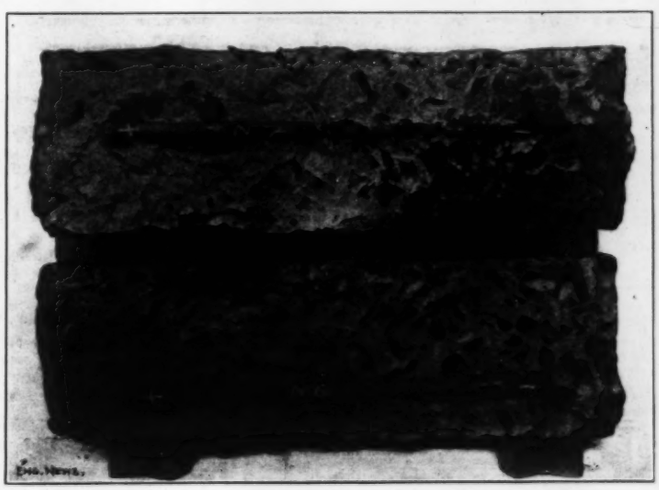


Fig. 6.
[Compare concrete at positive and negative ends.]

FIGS. 5 AND 6. CONCRETE BLOCKS NOS. 6 AND 7 BEFORE AND AFTER SPLITTING.

greater the voids (and therefore the greater the number of capillary tubes) the quicker the cracking occurred. Further, an experimental indication of hydrostatic pressure at the anode was offered by the appearance of the water bubbles already described just before cracking.

A second and more probable explanation of the cracking of the concrete is that first advanced by the writer as a result of experiments at the Massachusetts Institute of Technology in 1908, viz.: that the creation of rust at the anode caused the cracking. It is known that iron rust occupies a relatively greater volume than the iron from which it is formed. Thus, if a pin-hole be made in a tinned iron plate and a str... rusting agent be applied, rust will form u... the tin and gradually lift the layer of tin ... the iron to which it was adhering.

Consider now the case of the steel rod ... ided in concrete with a current of electricity ...ving. The steel anode is dissolved by the ani... the anion be that of a chloride or sulphate ...ut if the cement supplied silicate anions, the... would form insoluble compounds with the st... and, therefore, cause the precipitation of fer... com-pounds, e. g., rust, at or near the ano... The growth of this rust would then cause the ...crete to crack.

In connection with this idea, the follow... experimental data seem very significant:

(1) In all cases when small currents, ...hose heat effects were negligible, were used and ...racking occurred, rust has always been obser...d on the steel.

(2) In tests on the long blocks, althoug... both ends of these blocks were carrying the ...same current, the cracks in four different cas... only extended over that area where rusting oc...rred, in which the current direction was "from steel to concrete," i. e., at the negative end. (See Fig. 6.) The positive ends, in which the direction of current was "from concrete to steel," and no rusting occurred, did not crack, although the test was prolonged for considerable periods after the appearance of the crack.

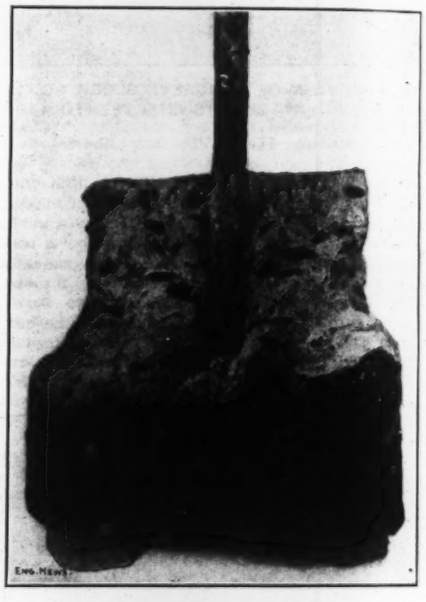


FIG. 7. Concrete Block No. 22.

(This block did not carry any current at all but was kept for comparison. Note the clean appearance of the steel and compare with Figs. 3, 4 and 6.)

(3) After 200 days of test none of the cubical blocks in which the steel was cathode cracked, although varying current values up to one averaging 0.148 amps. flowed. The concrete blocks used for this test were exactly similar in materials and construction to those which cracked when the steel was anode. When the steel was cathode, a forcible rupture of the concrete showed discoloration of the cement but no evidence of rust formation (see Fig. 3).

(4) The plane of the crack always extended through the axis of the steel, and in the cubical blocks did not extend more than 3½ ins. to 4 ins. down the side of the block, i. e., no further down the block than the steel rod penetrated. This would indicate that the steel had wedged open the concrete.

In some cases, where electrolytic action had been permitted for some time after cracking, an annular skin of compressed rust about 1/64-in. thick could be peeled off the steel anode.

(6) In the cases of the sandstone blocks when the steel instead of being grouted into its hole, was flexibly connected to the block by a little mercury, so that no pressure could be exerted

TABLE I.—7-IN. CONCRETE CUBES WITH CURRENTS FLOWING "FROM CONCRETE TO STEEL."

Number of block.	Proportions of cement, sand and stone by volume.	Age at beginning of test in days.	Duration of test in days.	Average current flowing in amps. d. c.	Constant potential applied in volts d. c.	Power consumed in watt-hours.	Remarks.
16	1:2:4	50	220	0.058	10	3,060	Plain concrete.
17	1:2:4	54	217	0.029	10	1,510	Hot parrafin painted on to make waterproof.
21	1:2:4	50	217	0.029	10	1,510	Coat of hot tar to make waterproof.
24	1:2:4	58	200	0.052	10	2,490	Three alternate coats of alum and soap to make waterproof.
25	1:2:4	56	200	0.061	10	2,920	Cathode of brass rod instead of steel as in other blocks.

N. B.—None of the above blocks cracked.

TABLE II.—7-IN. CUBES OF ARGILLACEOUS SANDSTONE AND BASALT WITH CURRENTS FLOWING "FROM STONE TO STEEL."

Number of block.	Material of block.	Duration of test in days.	Average current flowing in amps. d. c.	Constant potential applied in volts d. c.	Power consumed in watt-hours.	Remarks.
29	sandstone	200	0.148	10	7,110	Steel cathode; did not crack.
32	basalt	200	0.017	10	816	Steel cathode; did not crack.

TABLE III.—7-IN. CONCRETE CUBES WITH CURRENTS FLOWING "FROM STEEL TO CONCRETE."

Number of block.	Proportions of cement, sand and stone by volume.	Age at beginning of test in days.	Number of days before appearance of crack.	Average current flowing in amps. d. c.	Constant potential applied in volts d. c.	Power consumed in watt-hours.	Remarks.
19	1:2:4	69	37	0.023	10	205	Two coats of hot tar on exterior to make waterproof; cracked.
23	1:2:4	59	29	0.024	10	167	Three alternate coats of alum and soap to make waterproof; cracked.
26	1:2:4	56	?	0.009	10	434	Brass anode rod instead of steel as in other blocks. Did not crack after 200 days.

TABLE IV.—7-IN. CUBES OF ARGILLACEOUS SANDSTONE, BASALT AND BRICK, WITH CURRENTS FLOWING "FROM STEEL TO STONE."

Number of block.	Material of block.	Duration of test in days.	Average current flowing in amps. d. c.	Constant potential applied in volts d. c.	Power consumed in watt-hours.	Remarks.
28	sandstone	8	0.024	10	46	Steel anode; cracked.
38	sandstone	6	0.066	10	95	Steel anode; cracked.
37	sandstone	176	0.021	10	880	Steel and mercury anode; did not crack.
41	sandstone	146	0.141	10	4,940	Steel and mercury anode; did not crack.
31	basalt	200	0.003	10	144	Steel anode; did not crack.
..	brick	9	0.088	10	190	Steel anode; cracked.

TABLE V.—LONG BLOCKS 7 × 7 × 22 INS., REINFORCED, WITH ENDS EMBEDDED IN EARTH. CURRENT FLOW "FROM CONCRETE TO STEEL," ALONG STEEL, AND THEN "FROM STEEL TO CONCRETE."

Number of block.	Proportions of cement, sand and stone by volume.	Age at beginning of test in days.	Number of days before appearance of crack.	Average current flowing in amps. d.c.	Constant potential applied in volts d. c.	Power consumed in watt-hours.	Remarks.
24	1:1:2	64	66	0.035	10	535	Top surface kept wet.
12	1:1:2	136	40	0.023	10	221	Wet only from earth; no holes for thermometers.
13	1:1:2	...	...	.....	..	...	Dummy block.
22	1:2:4	120	39	0.025	10	234	Wet only from earth; no thermometer holes.
23	1:2:4	...	...	.....	..	...	Dummy block.
27	1:2:4	61	21	0.036	10	181	Top surface kept wet.

N. B.—All the blocks tested cracked in number of days indicated in column 4.

TABLE VI.—7-IN. CONCRETE CUBE TESTED DRY WITH CURRENT FLOWING "FROM STEEL TO CONCRETE."

Number of block.	Proportions of cement, sand and stone by volume.	Age at beginning of test in days.	Duration of test in days.	Current as shown on millimeter in amps. d.c.	Constant potential applied in volts d. c.	Power consumed in watt-hours.	Remarks.
34	1:2:4	73	125	0.000	10	0	No action during 125 days.

TABLE VII.—7-IN. CONCRETE CUBE WITH ALTERNATING CURRENT.

Number of block.	Proportions of cement, sand and stone by volume.	Age at beginning of test in days.	Duration of test in days.	Average current flowing in amps. a. c.	Potential applied in volts a. c.	Power consumed assuming unity p. f. in watt-hours.	Remarks.
18	1:2:4	85	188	0.2	47	42,400	Although the block became 10° C. higher than the water in which it was immersed it did not crack.
18	1:2:4	188	11	from 3 to 0.1 amps.	175	.....	The block cracked in 27 mins. after beginning test; the internal temperature then was 99° C.

by the steel on the block through the mobile [illegible]ary, the blocks did not crack with steel as a[illegible], after, in one case 176 days, and in the [illegible] 146 days of test. When, however, the s[illegible] was grouted firmly into two similar sand- [illegible] blocks, these cracked in 6 and 8 days, re- [illegible]tively, with smaller currents. (See table IV.)

In the case of concrete block No. 26 (Table I[illegible] a brass anode which could not rust was used instead of steel. The diameter of the brass rod was ¾-in. This block lasted 200 days with an average current of 0.009 amps. without cracking.

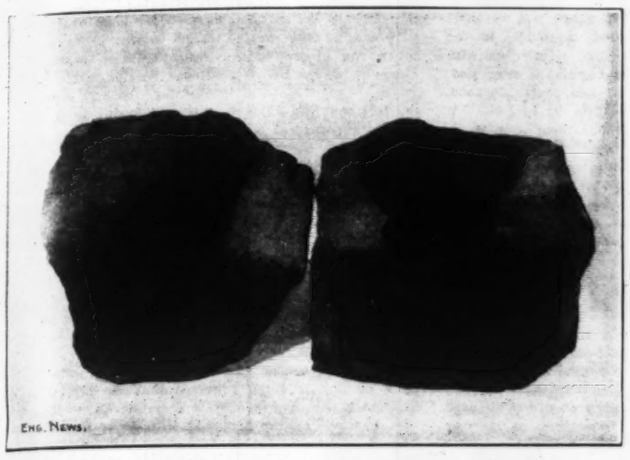


FIG. 8. SANDSTONE BLOCK NO. 38 AFTER BEING SUBJECTED TO CURRENT.

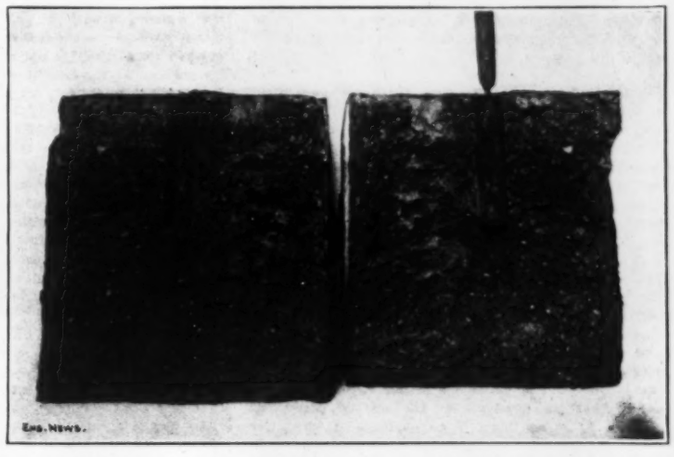


Fig. 9. VIEW OF INTERIOR OF BRICK BLOCK AFTER TEST.

All the above data would seem to pointedly connect the rusting of the steel with the cracking of the concrete.

With regard to the block of concrete tested with alternating current at a potential of 175 volts, the rapid fall in resistance with the increase of temperature would infer a negative temperature coefficient of resistance for concrete. It seems probable that, when the thermometer inserted in the block showed 99° C., the internal temperature was 100° C. At this temperature, water held in the voids of the block would be vaporized to form the steam which was observed escaping from the crack. Since the crack occurred a few seconds after the thermometer showed 99° C., it may be that the sudden pressure along a line of weakness by generation of this steam caused the cracking of the block.

Another explanation may be that the current flow became localized and confined along a line of low electrical resistance. The temperature may have then risen considerably along this path causing local expansion or contraction cracking and rupture. It is important to remember that the heavy alternating currents produced a crack quite different in appearance from and smaller in size than that produced by the smaller direct current.

Conclusions.

This series of tests tends to prove:

(1) That rusting and pitting of reinforcing and structural steel occurs at the anode.

(2) That this rusting by its growth causes rupture of the concrete and the development of large cracks.

(3) That very small currents, e. g., 0.02 amps. will cause such rusting and cracking.

(4) That when steel is cathode no rusting of the steel or cracking of the concrete will occur with currents up to 0.06 amps. during 200 days.

(5) That sandstone and brick will behave similarly to concrete, showing even less resistance to cracking.

(6) That damp earth supplies sufficient moisture to concrete to render it conducive to a current which will cause cracking.

(7) That alternating currents of the magnitude of 3 amps. will produce cracks by thermal action, but no rusting.

(8) That the thermal action, when measured by a thermometer, of currents of the magnitude of 0.05 amps. is negligible in blocks of concrete

The Briquetting of Iron Ores.*

By C. DE SCHWARZ.†

The question of briquetting iron ore is one which becomes of increasing importance every year, not only owing to the fact that iron ore in general, and lump ore in particular, are becoming more and more scarce, at least in Europe, but also because of the severe conditions, in regard to both chemical, composition and physical properties, imposed by modern blast-furnaces. The use of improved and more effective explosives in the iron mines, and the fact that iron ores have to be transported over long distances and frequently reloaded before they reach their destination, tend to increase the percentage of small and dust ore, to the disadvantage of blast-furnace working which—on account of the greater height of the furnaces themselves, the high pressure of blast, and the use of blast-furnace gases for gas-engines—requires an ore which is not too fine nor too dusty.

The blast, being of comparatively high pressure in modern blast-furnaces, will naturally blow out a considerable portion of the fine ore, which will mix with the escaping blast-furnace gases, causing well-known inconveniences. This is the more objectionable, as the blast-furnace gases are now, almost everywhere, utilized for driving gas-engines, for which purpose the gas must be almost entirely free from dust. The fine ore, during its downward passage in the blast-furnace, advances quicker than the lump ore, charged at the same time; consequently it is not exposed long enough to the beneficial reducing influence of the carbon monoxide gas arising from below. It therefore leaves the zone of reduction in the blast-furnace imperfectly freed from oxygen, and, as a consequence, clogs together as soon as it reaches the zone of carbonization, causing scaffolding, and even explosions.

A considerable number of methods for briquetting iron ore‡ have been brought out, but none as yet which can be applied generally with success. A few of the methods introduced into practice have proved successful, but only for certain kinds of ore, or in local circumstances and conditions. Some methods which have yielded favorable results with a particular kind of ore, have entirely failed with other ores. Experience has also shown that the method to be adopted must be modified to suit the nature of the ore, not alone with reference to its physical condition, but more especially with regard to its chemical composition. Most of the different methods which have been tried for briquetting fine-grained ore have proved to be too expensive, not alone with reference to initial outlay and cost of manufacture, but also, indirectly, on account of the great reduction of the contents of iron in the ore, owing to too great an addition of binding material.

The conditions for successful briquetting are—

1. The iron ore briquettes must have a certain resistance against mechanical influences. They must resist a pressure of not less than 2,000 lbs. per sq. in., and, when dropped from a height of 10 ft. on a cast-iron plate, they must not fall into dust although they may break into pieces.

2. They must resist heat. Heated to 900° C. they may commence to sinter, but they must not disintegrate into small fragments.

3. They should be capable of being placed in water for a certain time without softening.

4. They must resist the influence of steam at 150° C. without crumbling.

5. They must possess a certain amount of porosity in order to allow the carbon-monoxide in the blast-furnace to penetrate the interior of the briquette and to exercise its beneficial reducing influence. In order to test the briquettes for porosity, they are, after being dried, placed for about 25 minutes in water, during which time they ought to absorb not less than 12½% to 16% of water, according to the nature of the ore.

6. The binding medium, if any is used, should not contain noxious substances (sulphur, arsenic) to such an extent as to be injurious to the quality of the pig-iron produced.

7. The cost of producing briquettes should not exceed the difference in the prices between lump ore and fine ore.

The different systems of briquetting ore can be divided into those in which a binding medium is used and those in which no binding medium is used. The former may be subdivided into methods employing inorganic and organic binding materials respectively.

Briquetting Without a Binding Medium.

In most cases where no binding medium is used, the briquettes have to be heated at considerable expense; but there are exceptional cases where no heating is necessary notwithstanding that no binding medium is employed. This case presents itself where the iron ore contains a certain percentage of clay, because in such cases it contains in itself a binding medium. Clay iron ore and bean ore are instances. At Kertsch, in Russia, where bean ore is briquetted, the latter is mixed with 8% of water and made into briquettes under a pressure of about 5,600 lbs. per sq. in. At Ilsede, in Germany, where clay iron ore is used, it is mixed with the waste products coming from the rolling-mills and containing sufficient iron. The mixture, which is not allowed to contain more than 6% of water, is heated to about 75° C. and pressed into briquettes, the pressure being about 4,000 lbs. per sq. in. In both the above cases no heating of the briquettes is necessary, and no binding medium is used.

The results obtained at Kertsch and at Ilsede naturally suggest the addition of common clay to other iron ores (containing no clay) as a binding medium in order to make briquettes by means of a cheap medium, and without going to the expense of heating the briquettes. However, it has been found that—in order to achieve the desired result—it is necessary to add a comparatively large percentage of clay to the ore, thus indirectly reducing its contents of iron to too great an extent. Common clay contains, moreover, a high percentage of silica, requiring extra additions of limestone. The practice of using clay as a medium has therefore been abandoned, and it is only employed in cases where ferruginous clay is at disposal.

In some cases it has been sought to avoid the use of a binding medium, as well as the heating of the briquettes, by employing very high pressures, rising gradually to 11,000 lbs. per sq. in. The briquettes made in this way have been very firm and offer great resistance to mechanical influences, but when exposed to heat they expand and fall to pieces; besides which they are too dense, and this considerably interferes with their reducibility.

GROENDAL PROCESS.—Of all systems of briquetting iron ores without a medium, by heating the briquettes after they have left the press, the Groendal process, so called after the name of the inventor, has proved to be the most successful for magnetic ore. The following is a short description of this process: the raw ore, containing from 27 to 58% of iron, is broken up by means

*From a paper presented before the Iron and Steel Institute at Buxton, England, September, 1910.

†Liege, Belgium.

‡Several briquetting systems were described in Eng. News, Feb. 12, 1903, p. 141, where will be found also an account of the early history of briquetting iron ore in the United States.—Ed.

Name of the Place.	Raw Ores. Fe per Cent.	S per Cent.	P per Cent.	Concentrates. Fe per Cent.	S per Cent.	P per Cent.	Briquettes. Fe per Cent.	S per Cent.	P per Cent.
Flogberget	27.3	0.31	0.003	67.4	0.04	0.003	65.3	0.007	0.003
Herräng	40.2	1.21	0.003	67.3	0.17	0.002	65.5	0.003	0.007
Lulea	58.2	0.11	1.23	71.1	0.015	0.005	69.3	0.005	0.005
Strassa	46.8	0.03	0.015	69.2	0.015	0.003	67.1	0.005	0.003
Cornwall, U. S. A.	30.6	1.60	0.012	69.9	0.036	0.003	67.9	0.010	0.005

of a stonebreaker and then ground to sand in a ball-mill. From this sand the pure magnetic ore, the so-called "concentrate," is extracted by means of magnetic separators. The "concentrate," containing from 67% to 71% of iron, is moistened and made into briquettes about 6 ins. square and 2½ ins. thick, with rounded edges. No addition is made.

The briquettes are then laid in three rows edgeways upon small iron wagons and transported into a furnace heated with generator and blast-furnace gases. Heated and compressed air is supplied by means of a Körting blower in such quantity as to produce a highly oxidizing flame, whereby the magnetic ore (Fe_3O_4) is oxidized to peroxide of iron (Fe_2O_3). The sulphur is considerably reduced during this operation.

The accompanying tables gives the chemical composition of the raw ores, concentrates, and briquettes in different cases.

One furnace, about 150 ft. long and 5½ ft. wide, produces, on an average, 200 tons of briquettes in a week, the cost of production being given at about 83 cts. per ton of finished briquettes, exclusive of general expenses and royalties.

The briquettes are hard and porous, and quite suitable for the blast-furnace; but the cost of production appears to be rather high, in consequence of which the Gröndal process has not been much adopted except in Sweden. In Sweden there are at present 27 Gröndal furnaces at work, with a total output of about 300,000 tons of briquettes per year.

The reason why the Gröndal process is of special value to Sweden lies principally in the fact that the working of the blast-furnaces in that country is almost entirely based on the use of charcoal. The slag of charcoal-furnaces being—for well-known reasons—acid, it does not absorb sulphur, consequently nearly all the sulphur in the iron ore goes into the pig-iron instead of into the slag. This is also the reason why the blast-furnace owners in Sweden object to using any iron ore containing more than 0.015% sulphur. From the accompanying comparative table, it will be seen that the raw ore contains considerably more sulphur than the above-mentioned limit, and it is therefore absolutely necessary to reduce the percentage of sulphur in the raw ore, not only by means of the magnetic separator, but also by heating the briquettes to a high temperature (given at 1,400° C.) and in an oxidizing flame.

Although the percentage of iron in the briquettes is somewhat reduced, owing to the transformation of magnetite (Fe_3O_4) into peroxide of iron (Fe_2O_3), this disadvantage is more than compensated not only by the expulsion of sulphur, but also by the fact that peroxide of iron (Fe_2O_3) is much more easily reduced and requires considerably less fuel in the blast-furnace than black oxide of iron (Fe_3O_4).

Considering that charcoal is becoming more and more scarce from year to year, and, as a consequence, more expensive, the question of economizing fuel is of special importance to Sweden. Experience has shown that briquettes made of Fe_3O_4 (magnetite) require in the blast furnace 300 lbs. more charcoal per ton of pig-iron than those made of Fe_2O_3, equal weights and percentages of iron being taken in each case. This difference in the consumption of charcoal represents a reduction in the working expenses of about 6s. 6d. per ton of pig-iron in favor of Fe_2O_3 against Fe_3O_4. The success of the Gröndal process, notwithstanding its high cost, is therefore justified for Sweden, as well as in such other countries in which charcoal, together with sulphurous ores, was to be employed.

Considering that the melting point, and therefore the sintering temperature, of magnetite is comparatively low, the briquettes made of "concentrates" (Fe_3O_4) begin to sinter and to harden at a temperature of from 800° to 900° C. However, as already mentioned, the temperature is raised to about 1,400° C., in order to expel as much sulphur as possible. It may also be mentioned that the process of converting the Fe_3O_4 into Fe_2O_3, being an oxidation process, is accompanied by a development of heat, thus economizing fuel to a certain extent.

IN THE OPEN-HEARTH FURNACE.—The suggestion has been made of using briquettes made of "concentrates" directly in the open-hearth furnace, as a decarburizing and, at the same time, enriching addition to the metal bath. The use of iron ore in the open-hearth furnace for that purpose is already well known, but such ore must be comparatively rich in iron, and it must not contain noxious substances to such an extent as to interfere with the quality of the steel produced.

From the chemical analysis, given in the table, it will be seen that the "concentrates" (and therefore the briquettes made therefrom) quite fulfill these conditions, the percentage of sulphur in the "concentrates" varying, with the exception of those from Harräng, between 0.015% and 0.04%. Considering further, that, as a rule, only 25% of iron ore is used in the open-hearth furnace, the contents of sulphur in the ore added will be indirectly reduced to one-fourth (0.004% to 0.01%) in the finished steel, which is not high enough to interfere with its quality. In the case of briquettes made, as suggested, from concentrates, for use in the open-hearth furnace, it would not be necessary to heat them up to 1,400°; it would also not be necessary to oxidize them from Fe_3O_4 to Fe_2O_3, and to make them porous. For use in the open-hearth furnace, they can be pressed at a considerably higher pressure whereby they would become more compact, which is more advantageous for use in the open-hearth furnace, because they will then be specifically heavier, and therefore sink deeper in the bath, instead of floating upon the surface for a long time, like red or brown iron ore, which, with the exception of specular iron ore, is comparatively much lighter in weight.

As Fe_3O_4 commences to sinter at a temperature of from 800° to 900° C., the briquettes made of "concentrates" will become hard at this temperature, and need not be heated above it. This advantage, together with the fact that they need not be porous (and therefore not changed from Fe_3O_4 to Fe_2O_3) makes the briquettes considerably cheaper and richer in iron when used in the open-hearth instead of in the blast-furnace.

AGGLOMERATION.—In order to avoid the cost of briquetting, an attempt has been made to agglomerate the fine-grained ore in a rotary furnace. This method appears to be of special value in cases where the agglomeration can be combined with the roasting of the ore, should the latter be necessary or advantageous, as, for instance, when spathic ore, brown iron ore, or iron ore with a high percentage of sulphur is to be agglomerated.

The fine-grained ore to be agglomerated in a rotary kiln is mixed with coke-dust (which can generally be procured very cheaply) in order to reduce the oxygen in the ore. The Fe_2O_3 in the ore can thus be partly changed into FeO, which would enrich the ore in Fe, and, at the same time, reduce the temperature necessary for agglomerating.

Considerable difficulties have, however, been experienced with this method of agglomeration. First, it has been difficult to regulate the temperature in the rotary furnace in such a way that the necessary sintering would take place without melting. Secondly, it has been found that the ore, as soon as it commences to agglomerate, adheres to the inner fireproof lining of the rotary furnace, thus causing scaffolds, which have to be removed at considerable expense. These difficulties are more frequently experienced in cases where coal-dust firing is employed for heating the rotary furnace, because, in these cases, the ashes of the coal, consisting chiefly of silica and alumina, mix with the ore and cause scaffolds, besides indirectly reducing the contents of iron in the agglomerated ore. The use of gas instead of coal-dust firing may therefore prove advantageous in this case, partly because the temperature in the rotary furnace can be more easily regulated according to requirement, and partly because no ash becomes mixed with the ore.

Binding Mediums.

The use of slaked lime as a binding medium for fine-grained ore has been known for many years, and it has also been found that briquettes quite suitable for blast-furnace use can be made when the slaked lime is mixed with some granulated basic slag. Compared with other methods this process of briquetting is rather expensive and also considerably reduces the percentage of iron in the briquettes, because from 7% to 8% of binding material, containing no iron, has to be used. Besides this, the briquettes have to be exposed for a considerable time to fresh air in order that the calcium oxide in the briquette may absorb sufficient carbon dioxide, because hydrate of lime as such would lose its water in the upper portion of the blast-furnace, and the briquettes would therefore crumble to dust. The transformation of CaO into $CaCo_3$ also means another indirect reduction of the percentage of iron in the ore, not to mention that a great amount of space and extra labor are required for stacking and for keeping the briquettes, in order that this transformation may take place. This method of briquetting ore has therefore not found extensive application.

Burnt lime, either alone or mixed with clay or ashes, has also been tried, but without success. This may easily be understood from the fact that—owing to the presence of steam and carbonic acid in the upper portion of the blast-furnace—burnt lime absorbs water and carbonic acid, thus changing into hydrate of lime. These reactions—being accompanied with a certain evolution of heat—cause "upper heat," a serious inconvenience known to every blast-furnace manager. Besides these there are other disadvantages attending the use of lime and cement have also been tried as binding The former contains too much sulphur, and resists the influence of heat, although the briquettes stand humidity and mechanical influences.

More success has been achieved by using as binding medium a mixture of sand and slaked lime. Equal parts of these materials are mixed and ground into powder and then intimately mixed with the dust of After being moistened, the mixture is pressed into briquettes, charged into boilers, and exposed for some hours to the influence of superheated steam under pressure after which the briquettes are ready for the blast-furnace. About 6% of the above-mentioned binding medium is required. This method of briquetting iron ores depends on the fact that the silica in the sand—owing to the influence of superheated steam—is converted from the insoluble into the soluble condition, ready for combination. This method has given very good results in the quality of the briquettes produced, but it has not found very general use on account of its high working expenses as well as its high initial outlay.

Another method of briquetting, based on the same principle, consists in the use, as a binding medium, of basic blast-furnace slag, which was exposed to steam pressure as mentioned before. However, as nearly 10% of this medium is required to obtain good briquettes, it has been found that the percentage of iron in the ore becomes too much reduced.

Spathic ore, mixed with lime, is also successfully used as a binding medium, provided that the briquettes are exposed to steam pressure for a certain time. This process is based on the fact that hydrate of lime and carbonate of iron (spathic ore), when intimately mixed and exposed to steam pressure, become converted into hydrated ferrous oxide and carbonate of lime (limestone). The former, being of a gelatinous nature, serves as a binding medium and changes, later on, into hydrated sesquioxide of iron. This process is carried out in the following manner: A mixture of two parts of spathic ore with one part of lime, reduced to powder, is prepared. Of this powder 15% is added to the ore to be briquetted, the whole moistened—whereby the lime is converted into hydrate of lime—and made into briquettes under a pressure of about 6,000 lbs. per sq. in. These briquettes are packed—edgewise—on wagons, after which they are charged into boilers where they are exposed to a steam pressure of eight atmospheres for a period of 4½ to 6½ hours. In case spathic ore alone is to be briquetted, an addition of 6% of lime is sufficient. In the latter case cylindrical briquettes of about 5½ ins. diameter and 4½ ins. in height are generally made. The briquettes made according to this method are very good but expensive, besides which the plant requires a comparatively high initial outlay.

FLUE DUST.—Great success has been obtained in briquetting blast-furnace flue-dust, which is principally due to the fact that this by-product already possesses hydraulic properties, because—like cement—it contains lime, alumina, and soluble silica ready for combination. In addition to this, it has been found that by adding certain salts, such as chloride of magnesium, chloride of calcium, green vitriol ($FeSO_4 + 7H_2O$), or acids, such as sulphuric or hydrochloric acid, those hydraulic properties can be raised to such a degree that very suitable briquettes can be made from the dust.

Of these additions, chloride of magnesium ($MgCl_2$) has been found to be, generally speaking, the most suitable, because it is cheap (being a by-product in the manufacture of certain artificial fertilizers), and because it does not contain any noxious substances. Owing to the high temperature in the blast-furnace, the chloride of magnesium is decomposed into magnesium and chlorine. The former enters into the blast-furnace slag as MgO, and the latter combines with hydrogen to form hydrochloric acid. The acid further combines with the free lime to form chloride of calcium, which is finally absorbed by the water used for washing the blast-furnace gases. In some instances it has been observed that the iron portions of the furnace-top are slightly attacked, which is ascribed to the presence of hydrochloric acid not fully neutralized.

This process of briquetting, called after the inventor the Schumacher process, has given very satisfactory results, not only with reference to the quality of the briquettes produced, but also as far as cost of production and initial outlay are concerned. It must, however, be pointed out that the blast-furnace flue-dust used for briquetting, must be used almost immediately after having been removed from the catchers and that, like cement, it must be protected against humidity before briquetting. The installation for briquetting flue-dust should therefore be situated in close proximity to the blast-furnace from which the flue-dust is taken.

It is to be regretted that this process can only be used for briquetting blast-furnace flue-dust. An exception occurs in some instances where the chemical composition of the flue-dust is particularly favorable to the purpose, when an addition of about 40% of purple ore to the flue-dust has been found to be admissible. The latter acts, as it were, as a binding medium to the former

Another method of briquetting flue-dust consists in the use of basic blast-furnace slag. The mixture is first exposed to steam pressure. Owing to the influence of the steam the silica in the slag changes from the insoluble to the soluble variety, and combines with the lime in the flue-dust to a kind of cement, which acts as a binding medium. If the lime in the flue-dust is insufficient, another 4 to 4½% is added. The briquettes made in this way are quite suitable; but taking into consideration that from 8 to 12% of binding medium, containing no iron, has to be used, the contents of iron in the briquettes is too much reduced to make this method profitable.

ORGANIC BINDERS.—Organic matters, such as the waste lye (resulting as a by-product from the manufacture of sulphide cellulose) and molasses have been used for briquetting flue-dust as well as other iron ores. The lye is concentrated to a syrup, thus constituting a kind of pitch, called "Zellpech" ("cellulose-pitch") in Germany, where it is used. On an average, about 6% of this binding medium is intimately mixed with the flue-dust or ore, and pressed into briquettes under a pressure of not less than 9,000 lbs. per sq. in. The briquettes made with "cellulose-pitch" are suitable, but, as the binding medium is very expensive (about $10 a ton), the financial success of this method is rather doubtful.

The use of molasses as a binding medium was tried for briquetting the ferriferous residues of the aniline manufacturing process, as well as for briquetting flue-dust. One part of cheap molasses, by volume, is mixed with two volumes of silicious sinter ("Kieselguhr"), 0.4 parts by volume of carnallite and 100 parts by volume of the ore to be briquetted. The briquettes are allowed to dry in an annular furnace, such as is used for burning ordinary bricks. Here they are heated up to 1000° C, when they begin to sinter and to harden.

This method of briquetting is accompanied by high working expenses and considerable initial outlay. The employment is therefore only justified when the by-produce of the aniline manufacturing process, containing about 67% of iron, is to be made into briquettes. As before mentioned, this process was also tried for briquetting blast-furnace flue-dust, but it was abandoned, probably on account of the high cost.

Other Methods.

Besides the above-mentioned methods of briquetting fine-grained ores, or blast-furnace flue-dust, etc., there are numerous other methods of briquetting with or without a binding medium. In the former case soluble glass (alkaline silicate), asbestos, basic slag, naphtalin, paraffin, resinous soap, as well as other inorganic and organic materials, are used, and in the latter case smelting is conducted in a reverberatory furnace. Treatment with liquid iron, or in an electric furnace, has been proposed and also tried in practice, but in all cases without result. As there is also no reason to believe that these methods will ever be tried again, the author does not consider it necessary to go into details about them.

Conclusions.

From what has been said, it may appear that a universal method of briquetting fine iron ore, fulfilling the conditions already enumerated, has not been invented as yet, and probably never will be.

Taking the financial results of the different methods of briquetting into consideration, it is found that the methods of briquetting practised at Kertsch in Russia and at Ilsede in Germany appear to be the most economic, the working expenses, as reported, amounting only to about 25 cts. per ton of briquettes. As already previously mentioned, this method can, however, be applied successfully only when the ore contains sufficient hydrate of alumina to serve as a binding medium.

The manufacturing expenses of briquettes by the Gröndal process amount to about 83 cts. per ton of briquettes, exclusive of general expenses, redemption, and royalties, for which at least 32 cts. will have to be added, thus resulting in a total expense of $1.15 per ton of briquettes. This would be far too high to allow of the general introduction of this process. However, the Gröndal process is of particular value for Sweden, where its use has become almost unavoidable in order to utilize the iron ore of that country.

Of all the different methods employed for briquetting blast-furnace flue-dust, the Schumacher process has given the best financial results, the cost of briquetting according to that method amounting to only 41 cts. per ton briquettes excluding royalty.

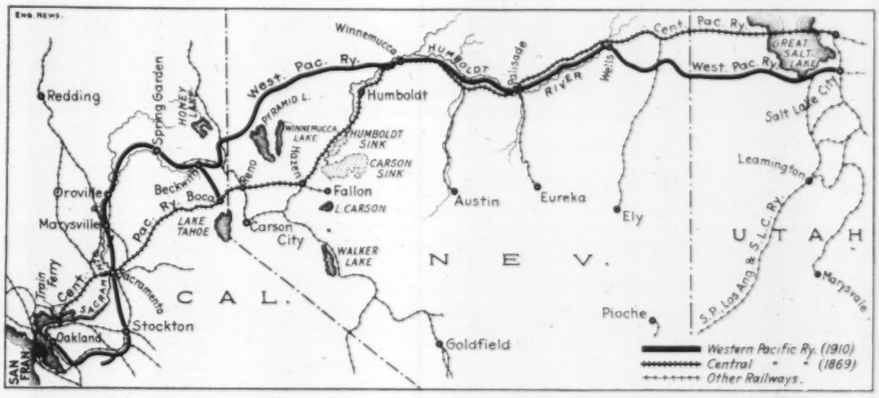
The other methods of briquetting iron ore flue-dust and other ferruginous residues of other industries, as described before, have given less favorable financial results, the cost of briquetting amounting to from 61 cts. to 92 cts. per ton briquettes. Besides this, it must be mentioned that where a binding medium is used, on an average about 7% is required to be added to the ore, thus reducing considerably the percentage of iron. In several cases it has also been found necessary to stack the briquettes for several weeks in the open before they could be used, thus requiring a good deal of space and extra labor for transporting and handling.

Finally, it may be mentioned that at present an establishment for making briquettes is being erected at a Belgium works acording to a new process recently introduced. According to this method from 2½% to 4½% of binding medium, costing about $3.90 a ton, is used. The initial outlay for a plant turning out five tons of briquettes an hour, amounts to about $12,500, and the manufacturing expenses, inclusive of general expenses, to 37 cts. per ton briquettes. The briquettes fulfil all the requisite conditions and can be used within 24 to 36 hours after having left the press, no heating or any additional work being necessary. By this method, not only fine ore, but also rolling-mill and forge-scale (Fe_3O_4) have been briquetted with success, the latter having been successfully used as an enriching and decarbonizing addition in the open-hearth furnace.

The Western Pacific Ry.

The Western Pacific Ry., which forms the western end of a new route to the Pacific coast, was opened for passenger traffic on Aug. 22, and had been open for freight traffic some time before that date. The railway is notable from an engineering and operating point of view on account of its easy grades and low summits in crossing the Rocky Mountains (specifically the Sierra Nevada range). These features involved great first cost of construction, but were warranted by the purpose of obtaining a low cost of operation on a line which has great traffic prospects and which competes with other lines having less favorable conditions.

The railway extends from Salt Lake City to San Francisco. A line following its general route has been proposed many times, even before the construction of the Central Pacific Ry. (1863-69). In 1905, the project was taken up by the Gould System as its extension to the coast. This system now includes the Missouri Pacific Ry. from St. Louis to Pueblo, Colo. (640 miles), the Denver & Rio Grande Ry., thence to Salt Lake City (624 miles), and the Western Pacific Ry. thence to San Francisco. This makes a total distance of 2,185 miles from the Mississippi River to the coast.



MAP SHOWING THE RELATIVE LOCATION OF THE WESTERN PACIFIC RY. (OPENED IN 1910) AND THE CENTRAL PACIFIC RY. (OPENED IN 1869.)

The new railway is parallel with and a direct competitor of the Central Pacific Ry. (which was the Pacific end of the first transcontinental railway and is now a part of the Southern Pacific Ry. System). The Western Pacific Ry., starting at Salt Lake City, Utah (elevation 4,224 ft), has a length of 921 miles to San Francisco, maximum grades of 1%, and two summit elevations of 5,712 and 5,018 ft. The Central Pacific Ry., starting at Ogden, Utah (4,296 ft.), has a length of 786 miles, maximum grades of 2.2% and 2%, and two summit elevations of 7,017 and 6,150 ft. As far as the eastern connections are concerned, however, the older line has an advantage. The Union Pacific Ry., with which it connects, has a summit elevation of 8,247 ft. (at Sherman), while the Denver & Rio Grande Ry. (with which the new line connects) rises to 10,240 ft. in the Tennessee Pass and has a more severe profile.

In comparing the two parallel lines from Salt Lake to the coast, the different conditions under which they were built must be taken into account. The Western Pacific Ry. was built to take a share in an important and increasing traffic, so that a very high construction cost was warranted in obtaining a line of large traffic capacity, economical in operating expenses, and free from future heavy expenses in grade reductions or similar improvements. Its cost has been given as averaging $60,000 per mile. The Central Pacific Ry. was built largely as a military or strategic line to form a bond of union between the main part of the country and its Pacific Coast territory. Important freight traffic was not considered a possibility at that time. Rapidity and low cost of construction were essential features, and the location and construction of this line were notable feats in railway engineering. As an operating line, the newer railway has important advantages, in spite of its greater length. On the other hand, many improvements have been made on the Central Pacific Ry. and others are proposed.

At Salt Lake City, a large passenger station for the joint use of the Western Pacific Ry. and the Denver & Rio Grande Ry. has been built at a cost of about $1,000,000, including the yards and terminal facilities. At the Pacific end, the railway terminal is at Oakland (the same as the Central Pacific), with a steam ferry transfer of 3½ miles across the bay to San Francisco. The company has 360 acres for railway terminals at Oakland, and 269 acres at San Francisco. At the latter city, the water-front property is about 216 acres, the balance being for a local freight station in the heart of the city, and connected with the water-front by a tunnel. The three longest tunnels on the line are as follows: Spring Garden, 7,306 ft.; Beckworth Pass (summit), 6,006 ft.; and Flower Lake, 5,657 ft. There is also a tunnel 4,287 ft. long. The Flower Lake tunnel was notable in being entirely dry, and it is believed to be the longest tunnel in this country in which no water was encountered. The tunnels are 16 to 17 ft. wide and 22½ ft. high from subgrade, with semicircular roof. There are numerous steel bridges, but very few trestles. The assumed live load for bridges consists of two 177½-ton locomotives of the 2:8:0 class, followed by a train load of 5,000 lbs. per lin. ft. The construction of the line is very substantial, so as to largely eliminate future expenditures on grade and curve reduction, the strengthening of bridges and other improvement work.

The maximum grades are 1%, and these aggregate about 120 miles against eastbound and 52 miles against westbound traffic. The profile is such as to enable very heavy trains to be handled. At two points, loops are required for the development necessary to maintain a 1% grade, and one of these has a horseshoe curve about five miles in length. The grades are compensated for curvature at the rate of 0.035% per degree. The sharpest curves are of 10°, and all over 2° have transition curves. The track is laid with 85-lb. rails of the Am. Soc. C. E. section, and a considerable proportion of these are of open-hearth steel. All rails for curves of 1° and over are bent in a machine to the proper curve. The tracklaying was completed in November, 1909.

An important feature is the practical freedom from snow troubles, due to the low elevations, and there are no snowsheds on this line. This avoids delays to traffic, and results in a large sav-

ing in the cost of building and maintaining snowsheds and operating snow plows. It is stated that during the three winter months of December, January and February, 1907, the total snowfall on the summit was only 21 ins. (with none in February). During the same period the total snowfall at the summit of the Central Pacific Ry. was 284 ins., with 148 ins. in February alone.

While the Western Pacific Ry. practically parallels the older line, it will open up some territory of its own, which is not served by or tributary to the latter. This territory includes timber, mining, grazing and agricultural districts, and large areas which will be developed by irrigation. A number of new towns have been established.

Mr. Virgil G. Bogue, M. Am. Soc. C. E., was Vice-President and Chief Engineer during construction, but resigned after the completion of the road. The present Chief Engineer is Mr. T. J. Wyche, who was one of the Division Engineers on construction.

Puzzolan-Portland Cement; A Suggestion for an Improved Hydraulic Cement.

By EDWARD DURYEE.*

All who have been engaged in the development of the Portland cement industry are proud of the mechanical and technologic excellence of American processes and the reliable character of the numerous brands of Portland cement now on the market. Manufacturers are grinding to greater fineness, burning the cement better and in every particular exercising greater care than ever before in turning out uniform, sound and high grade products.

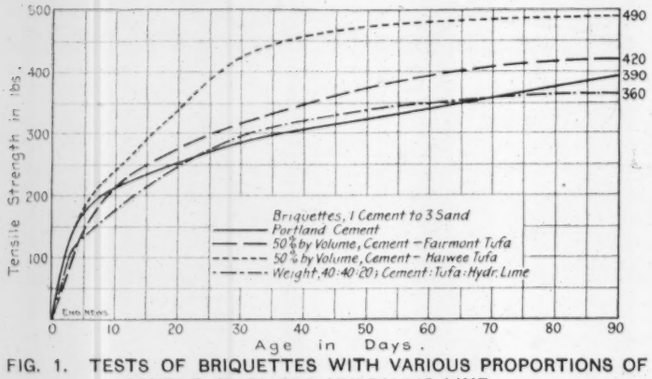


FIG. 1. TESTS OF BRIQUETTES WITH VARIOUS PROPORTIONS OF CEMENT, TUFA AND HYDRAULIC LIME.

Although the cement is of higher grade than formerly, still, in general use in concretes, it goes no further, the color is no better and the concrete is no denser than was formerly the case.

The writer has been impressed by the frequent complaints of leaking reservoirs, tunnels, cellars and walls of buildings, by the discolored superstructural walls of buildings and the occasional destruction of mortars in sewers and harbors. It is therefore with a conviction of the need as well as the possibility of improvement that he advocates the use of the silicious-Portland or puzzolan-Portland cement now being used to a considerable extent on the Los Angeles Aqueduct and which is the product of regrinding Portland cement with a puzzolana. The eastern states are virtually precluded from using such a mixture because of the lack of natural puzzolanas, but the Pacific Coast abounds in immense and unused deposits of the very best grades of these materials, and is thereby qualified to lead the cement industry in this line.

There is an universal field for an improved Portland cement that shall secure mortars permanently waterproof and of better color for architectural purposes, and it is for the purpose of explaining this and calling the attention of engineers and architects to the means for obtaining this cement that this paper is prepared.

It is well known that the finer ground cement and tufas are the greater is their hydraulic efficiency, and the more completely will they fill the pores of mortars. This filling the pores of mortars is the only effectively permanent method of making mortars waterproof, and by using a finely-ground cement and puzzolana this may be accomplished. In finely-ground puzzolanas the silica is in an active or "soluble" form capable of uniting with hydrated lime and forming crystals to fill the pores of the mortar in a colloidal form. We may depend upon these crystallized compounds retaining their voluminal condition permanently whereas many waterproofing compounds in common use are composed of colloidal solutions that will shrink under alternate wet and dry conditions and in time lose their efficiency.

Ancient Puzzolan Cement.

In Italy the old Roman cements have always been used and there are quay walls, aqueducts and buildings standing there as old as the Christian era.

ROMAN CEMENT.—The Roman cement was composed sometimes of nine parts of puzzolana or volcanic scoria mixed with one part of slaked lime; in other cases for use underground, two parts of Vesuvian puzzolana was mixed with one part of slaked lime.

In building retaining walls along the Tiber, the wall proper is first laid up with blocks of tufa as quarried in sizes of 8 to 13 in., laid in the last mentioned mortar; no sand is used in the mortar. The wall is then faced with hewn travertine in blocks of 18x30 in., and the whole is then curbed with peperino; this latter stone is mostly used for trimmings, sills, curbs and cornices. Travertine was extensively used by the ancient Romans for monumental buildings such as the Colosseum, Aqueduct, and the Church of St. Peters.

The puzzolan earth used for mortars is said to cost about 54 to 80 cts. per cu. yd.

NEAPOLITAN CEMENT.—Puzzolan di Bacoli is quarried near Puteoli at Bacoli and is used there. To make cement, two parts of this are mixed with one part slaked lime, and one part of this cement is mixed with two parts Vesuvius stone (broken lava) about walnut size. This is used for concrete for foundations and waterfront buildings. The formula for concrete claimed to be as good as was used by ancients is:

Puzzolano di Bacoli	2 pts.
Slaked lime	1 pt.
Vesuvius stone	6 pts.
Water to work properly.	

The price of this mineral is 2½ lire per cu. m. or 50 cts. for 1¼ yds., and at wholesale 2 lire per cu. m. or 40 cts., equivalent to 32 cts. per cu. yd. It is exported to South America.

The Italian cements were not ground nearly so fine as is advocated in this paper and on that account were not so dense.

Prevention of Deterioration of Concrete.

It is conceded by the best cement investigators that there is liability of chemical deterioration in Portland cement concrete exposed to sea, sewage and alkaline water unless means be taken to prevent it. Fortunately, this prevention can be accomplished by specially preparing the cement by grinding with it a puzzolana; as mentioned in the opening of this paper this practice has been followed in Europe and it should be adopted in America. Quoting from an editorial in "Cement and Engineering News" for August, 1910, on the "Waterproofing Qualities of Colloids":

> Waterproofing has frequently to be resorted to. This is especially true in sea water, sulphur and alkaline water (sewage waters included), in which cases the waterproofing compounds prevent the decaying influence of the chemicals dissolved in the water. . . . Effective waterproofing and protecting of Portland cement [against] water containing corroding salts is only possible by [a] mixture of substances which are principally compo[sed] of the three colloids, silica, alumina and iron oxide [and] elements contained in cements, besides the calc[ium] oxide. Such substances are termed puzzolanas, ar[e] natural, and are found in the form of volcanic [ash], or are obtained by granulating blast furnace [slag], or by drying or baking clays or shales. In Portla[nd] mortar the lime becoming free in the process of [hy]dration following the mixing of the hydraulic ce[ment] with water, acts upon the colloidal bodies (of which [silica] is the most effective and alumina the least desir[able] with iron oxide taking an intermediate position) a[nd] swells them slightly in a similar way as rice grains [swell] in boiling water.

California is well supplied with deposits of natural puzzolanas and it is easily possible to furnish the western cement market with the superior waterproofed puzzolan-Portland cements advocated above.

The results of tests on the behavior of hydraulic cements in sea water covering a period of five years, have appeared in a report of the Royal Testing Laboratory of Germany, under the title of "Mitteilungen aus dem Kgl. Materialprufungsamt." These results show the advantages of puzzolan-Portland cement, particularly in lean mortars, and for long periods. A review of this report lately published in English by H. Burchartz (See Engineering News, Nov. 3, 1910) is said to present the results in as unfavorable a light as possible to puzzolana mixtures. In very rich mortars, straight Portland cement mixtures are stronger than those of puzzolana-cement. These rich mortars are not however used in practice, and in ordinary proportions the puzzolana mixtures show superior strength and economy.

In experimenting with puzzolana mixtures, some unfavorable results have been obtained when the materials have not been properly prepared, as for example, the report of an Austrian Architect's Association, in which the tests were made with a mixture of cement and puzzolana, wherein the trass was so coarse that half of it failed to pass a 50-mesh sieve. Fineness of grinding and uniform mixing are of course essential in securing good results.

In a laboratory way, Bleininger ground Portland cement and puzzolana together in equal proportions, and the product showed a much greater resistance to the action of acidulated water than did straight Portland cement. He suggested:

> If practice should confirm this suggestion, the durability of exposed cement surfaces, such as sea walls, cement blocks and reservoir walls, could be thus improved cheaply and satisfactorily. It should be the task of Portland cement manufacturers to study these questions and prepare for the market, cements especially suitable for exposed work. Much of the lack of confidence which existed in certain quarters in years past regarding the use of cement would thus be eliminated.

By regrinding ordinary Portland cement, the proportion of flour cement, the active part of cement, which by crystallization gives strength to mortars, is greatly increased. The process of grinding puzzolana with cement exceedingly fine, brings the active silica of the puzzolana into intimate contact with the particles of the cement, and they take in the chemical rearrangement of the crystallization attendant on adding water. There is thus obtained an auxiliary hydraulic reaction, and the primary strength of Portland cement is increased by the strength of puzzolana cement. This increased strength is rendered all the more valuable in that the mortar is given a highly silicious character, and thereby rendered more proof against chemical action, while the fine grinding contributes to the greater impermeability of the mortar.

Puzzolan-Portland Cement on the Los Angeles Aqueduct.

The writer has been investigating deposits of puzzolanas in California during the past three years and a partial report of these investigations was published in the Third Annual Report of the Los Angeles Viaduct for 1908, p. 80-83. He has had charge of building and operating for the first season, two mills on the line of the Los Angeles Aqueduct for the regrinding of these puzzolanas with Portland cement. Deposits of tufa, a puzzolana, were found near the line of the Aqueduct at convenient points, one at Fairmont

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near the southern end of the Aqueduct, where Mill No. 1 is located and another at Haiwee, where Mill No. 2 is located. Each mill completed cost about $25,000. The output of both plants has been about 100,000 barrels, which has gone into the construction of the Aqueduct. Satisfactory construction work has been done with the cement. The accompanying stress curves demonstrate the excellent strengths of the cement but do not of course show its waterproofing character.

The accompanying curves (Figs. 1-2) were made up by using averages of many tests and demonstrate several interesting points. By far the strongest exhibit of tufa mixtures is that shown by the mixture of 40% Portland cement, 40% tufa and 20% hydrated lime, ground together. This product proved stronger than clear Portland cement mortars as follows: In 7 days 20 lbs. stronger and in 28, 60 and 90 day periods about 100 lbs. stronger at each period.

The mixture of 30% tufa and 60% Portland cement showed about the same strength as the mixture of 62½% tufa and 37½% Portland cement. All three of the above mixtures showed higher tests than the clear Portland cement mortars at all periods after 28 days.

Of these tests the 90-day breaks were made in the laboratory of the Los Angeles Aqueduct Cement Mill and the 180-day breaks in the City Engineer's laboratory. All the mixtures except the one containing slaked lime, which was ground in a laboratory ball mill, were ground in the Aqueduct regrinding plants at Fairmont and Haiwee, and the samples were taken from cement used in the construction of the Aqueduct.

The materials used in three tests have the following weights per cu. ft.

Portland cement, loose	88 lbs.
Tufa and cement, equal parts by weight, loose	69 lbs.
Equal parts by weight, shaken down	80 lbs.
Tufa coarse ground in ball mill	69 lbs.
Tufa fine ground in tube mill	55 lbs.

The composition of the Los Angeles Aqueduct tufa is as follows:

	%	%
Silica	67.10	70.40
Alumina and feric oxide	15.60	15.92
Lime	2.01	1.16
Magnesia	1.75	....
Alkalis and moisture	not found	

The writer submits the following specifications for a waterproofed hydraulic cement which it would be possible to supply in the California market and which would meet the conditions advocated by authorities on waterproof cement for sea and other impure water constructions as well as for general use.

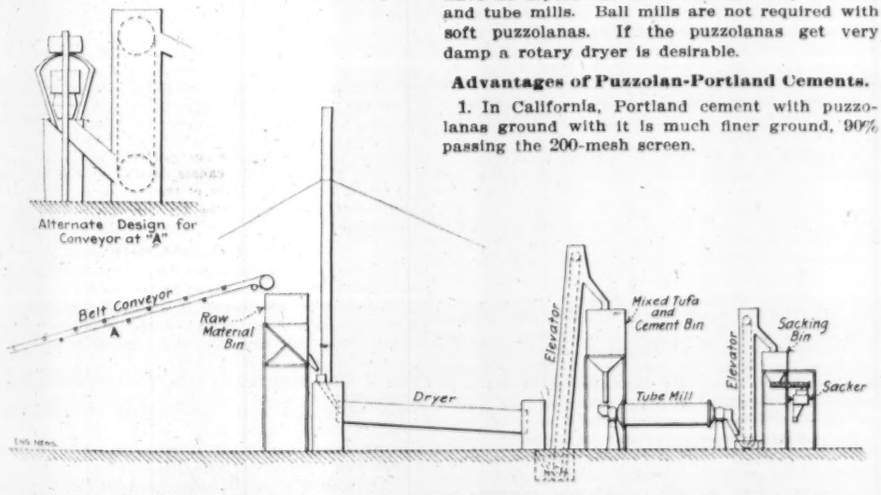

FIG. 3. TYPICAL GRINDING-MIXING PLANT FOR PRODUCTION OF PUZZOLAN-PORTLAND CEMENT.

Proposed Specification for Waterproofed Cement.

The base of the cement and composing at least 50% by weight of the product shall be Portland cement.

FINENESS.—This cement shall have been reground with puzzolana, the amount to be named in this specification; the finished product to contain from 10 to 50% puzzolana, the finished cement having a fineness of 90% passing a 200-mesh screen. Hydrated lime may be an element of the cement for some purposes and by express agreement.

COMPOSITION.—Preference will be given to a cement showing a minimum percentage of alumina and lime, particularly alumina which is the constituent most liable to decomposition from the action of impure waters.

TIME OF SETTING.—It shall develop initial set in not less than 30 mins. and final set in not less than 10 hrs.

TENSILE STRENGTH.—The minimum requirements for tensile strength for briquettes 1-in. square in section shall be as follows, and shall not show retrogression within the periods specified:

One part cement, three parts standard testing sand.	
1 day in moist air and 6 days in water	200 lbs.
1 day in moist air and 27 days in water	300 lbs.

Neat tensile tests will not be required, but crushing and permeability tests are recommended where facilities permit.

SOUNDNESS.—Pats made in the usual way and submitted to the boiling test shall remain hard and show no signs of disintegration.

NOTE.—It will be noticed that the changes in standard cement specifications proposed involve finer grinding, omitting or lowering the neat tensile tests, and the addition of a puzzolana, and when wanted, hydrated lime.

The accompanying sketch (Fig. 3) gives an outline of the layout of a typical plant for the regrinding and mixing of tufa with Portland cement to make puzzolan-Portland cement. The sketch differs from the plans for mills built on the Los Angeles aqueduct, in that the latter have no dryers but do have a crusher, and ball and tube mills. Ball mills are not required with soft puzzolanas. If the puzzolanas get very damp a rotary dryer is desirable.

Advantages of Puzzolan-Portland Cements.

1. In California, Portland cement with puzzolanas ground with it is much finer ground, 90% passing the 200-mesh screen.

2. The reground cement with puzzolana is unfailingly sound.

3. It makes a smooth, impermeable surface, proof against the chemical action of seawater and sewage and alkali.

4. This cement exhibits a more continuous ratio of increase in strength in sand mortars and for longer periods than is true of ordinary commercial Portland cements.

5. While the mixed Portland cement and puzzolan-cement is superior to Portland cement, it can be sold at lower prices than commercial Portlands in the California market on account of the abundance and availability of local puzzolana deposits.

6. This puzzolan-Portland cement produces a surface of more uniform color and less liable to unsightly lime efflorescence. Using a correct proportion of water and with the addition of puzzolana containing active silica to combine with the lime, largely eliminates the lime stains.

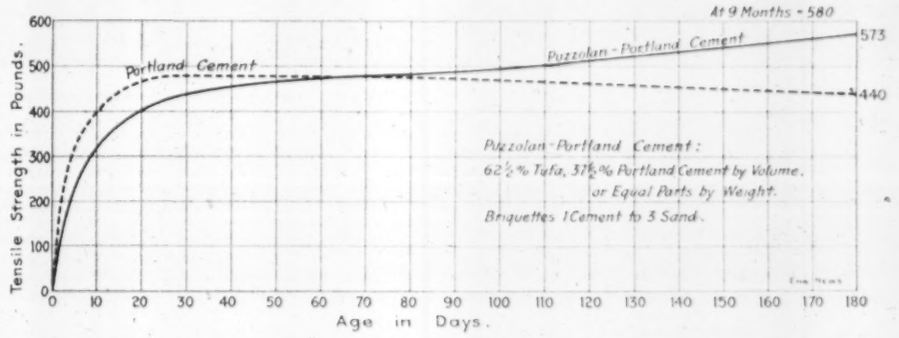

FIG. 2. TESTS OF BRIQUETTES OF PORTLAND CEMENT AND OF PUZZOLAN-PORTLAND CEMENT.

7. The puzzolan-Portland cement possesses greater volume in equal weights.

Tests on Waterproofing Concrete.

In connection with the theory expressed at the beginning of this article that the only way to waterproof concrete effectively is to provide in the dry mix some finely ground material that will fill up the pores and thus render the set concrete impermeable, attention is called to the following set of tests. These experiments were undertaken in 1908 with sands obtained along the line of the Los Angeles Aqueduct on the Owens River region, the object being to determine what materials might be added to the concretes to render them impermeable to water and how these additions might affect the strength of the concretes.

The samples of sand were tagged numbers 1 to 6. Mechanical analysis for fineness were made from No. 1 and No. 2, and the remaining samples were mixed and an analysis made of the average of Nos. 3, 4, 5 and 6. One sample of a California brand of Portland cement was used in all the concrete test cylinders. Test piece "A" was made with No. 1 sand, piece "B" was made with No. 2 sand, and pieces "C," "D," "E" were made with the average of Nos. 3, 4, 5 and 6 sands. Briquettes were made from the mortar used for the permeability tests in each case in order to determine the effects of the waterproofing materials on the strength of the concretes.

The molds used for making the cylindrical sections of concrete were prepared by taking cast-iron caps for 6-in. pipe, tapping out the solid cap end to reduce for ¾-in. nipples for connection to the water pressure pipe line. The straight sides were also channeled, with two circular channels to enable the concrete to bond strongly to the iron shell. By the use of these forms concrete cylinders 6 ins. in diameter and 6 ins. high were obtained. The concretes were left in the forms throughout the tests.

FINENESS OF OWENS RIVER SANDS.—

	No. 1	No. 2	Average 3, 4, 5, 6
Passing ¼-in. mesh	100.00	100.0	100.0
Passing ¼-in. and left on No. 10 screen	43.24	7.4	5.4
Passing No. 10 and left on No. 20 screen	22.54	13.0	27.0
Passing No. 20 and left on No. 30 screen	10.85	14.9	19.2
Passing No. 30 and left on No. 40 screen	6.28	12.2	10.2
Passing No. 40 and left on No. 200 screen	16.02	50.9	33.0
Passing No. 200	1.32	2.7	2.4

The various samples tested as follows:

"A" CONCRETE.—

No. 1 sand, 9 lbs.; dry, ground Tehachapi clay 5% or 0.63-lb.; Portland cement, 3¼ lbs. The materials were mixed thoroughly dry, then 19% of water, made milky with slaked lime, was added and the mortar was thor-

oughly mixed wet. The mortar worked fat and of good consistency. The tensile strength of mortar briquettes was:

14 days	190 lbs.
28 days	198 lbs.
2 mos.	262 lbs.

"B" CONCRETE.—

No. 2 sand, 9½ lbs.; dry, ground Tehachapi clay, 2% or ¼ lbs.; Portland cement, 3¼ lbs. The materials were mixed dry, then 1,021 cu. cm. of water containing 23 gr. of alum, equivalent to a 2½% solution of alum, was added. The water was 22% of the mortar. The mortar worked stiffer than "A" and stood some tamping in the mold before it quaked. The tensile strength per sq. in. of the mortar briquettes was:

14 days	176 lbs.
28 days	284 lbs.
2 mos.	296 lbs.

"C" CONCRETE.—

Average sands, 9½ lbs.; dry, ground Tehachapi clay, ¼ lb.; hydrated lime, 0.44 lb.; Portland cement, 3¼ lbs. The materials were mixed dry, then 1,000 gr. of water carrying 2½% silicate of soda was added. The tensile strength per sq. in. of the briquettes was as follows:

14 days	134 lbs.
28 days	200 lbs.
2 mos.	236 lbs.

"D" CONCRETE.—

Average sands, 9½ lbs.; stearate of lime, 2%; Portland cement, 3.2 lbs. The materials were mixed dry and 19% of water was added. The mortar was not so fat and was wetter than previous mortars containing clay The tensile strength per sq. in. of the briquettes was as follows:

14 days	140 lbs.
28 days	200 lbs.
2 mos.	216 lbs.

"E" CONCRETE.—

Average sands, 9½ lbs.; Portland cement, 3.17 lbs.; water, 19%. No waterproofing mixture was used. The tensile strength per sq. in. of the briquettes was as follows:

14 days	112 lbs.
28 days	206 lbs.
2 mos.	186 lbs.

Briquettes were also made with standard testing sand for comparison of tensile strengths of the preceding mortars with standard mortars. Two sets were made, the "wet" mortar being made with 19% water (the quantity used in the concretes made for the test cylinders), and the "dry" mortar being made with 10% of water.

The tensile strength per square inch, with the standard sand, was as follows:

	14 days.	28 days.	2 mos.
"Wet" mortar	176 lbs.	230 lbs.	302 lbs.
"Dry" mortar	240 lbs.	246 lbs.	294 lbs.

TREATMENT OF TEST CYLINDERS.—The test pieces were all made on the same date and under the same conditions. They were all kept damp for one month and were then connected to the Los Angeles City water main, under 60 lbs. pressure, continuously for 24 hours. At the end of this time the "E" block showed sweating on the lower end, but all the others remained perfect. This pressure was continued for a month continuously, without any change. During all this period all the treated mortars remained dry on the lower surfaces, but the untreated block was always damp, although not enough water to measure percolated through it.

After a month's pressure of 60 lbs., the pressure was raised by hourly stages for six hours as follows:

9.15 a.m.	60 lbs.
10.15 a.m.	80 lbs.
11.15 a.m.	100 lbs.
Noon	A few drops from the "E" block alone.
1.15 p.m.	120 lbs.
2.15 p.m.	150 lbs.
3.15 p.m. (for one hour)	200 lbs.

No change was noticed and none was damp with the exception of "E."

CONCLUSIONS.—The use of any one of the waterproofing materials tried in these experiments, with these sands, rendered the 6-in. concrete masses practically impermeable under favorable conditions and during the period of the tests.

2. For the purposes of the Los Angeles Aqueduct, the addition of small percentages of ground clay and hydrated lime answer the purpose as well as do the other mixtures tried. The concrete in the Aqueduct will be perpetually wet.

3. The addition of these materials did not during the two months' period of the testing effect injuriously the strength of the concrete; this might not hold true for long periods.

The use of the reground Portland tufa cement would evidently afford a denser, more perfect waterproofing medium as it is finer ground than the cement used in these experiments and the tufa with hydrated lime is a permanent colloid to fill all pores.

The Function of the State Engineer in the Arid and Semi-Arid States.*

By SAMUEL H. LEA,† M. Am. Soc. C. E.

Since irrigation became an established institution in this great western country, the necessity of regulating the distribution of the water-supply by statute and the administration of the water laws by some central authority in each state has been realized, and this necessity has been met by the creation of the position of State Engineer.

While the office of State Engineer is not peculiar to the arid and semi-arid states, it is true that these states have, for the most part, provided themselves with state engineers whose duties have to do chiefly with irrigation. These duties, as a rule, range from the mere making of hydrographic surveys to practically complete control of the water-supply, varying according to the water laws of the different states. It is true, therefore, that in most of the western states, whatever there is of public control of the use of water centers in the office of state engineer. A comparative study of the work of these engineers involves, therefore, the whole subject of public control of water.

Defining Rights.

Since the state engineer is charged with the distribution of water to those entitled to its use, an essential requisite to such distribution is the establishment or determination of well-defined rights. It is a well-known fact that a majority of water rights in the United States were acquired without public supervision, the procedure conforming in most cases to local customs and usages prevailing at the time. While certain general principles relating to the nature and limitations of water rights were recognized in the several states, no method was provided for the application of these principles to any particular right except by judicial procedure. A careful determination of these old, indefinite rights is essential for equitable public control of water appropriations from streams, because all new rights are subordinate to earlier rights and, in order to know definitely the extent of new rights, it is necessary to accurately define the old rights in a stream.

In order to furnish information concerning present methods employed to define old water rights, a description of the procedure followed in my own state, South Dakota, will be given.

The Practice in South Dakota.

Prior to the year 1905 there was no state supervision of flowing streams in South Dakota, and local customs were followed in the matter of appropriating water for beneficial purposes. In the western part of the state considerable placer mining was done in the gulches and along the streams in the Black Hills. Such operations required the use of flowing water in most instances, and in such cases the appropriation would be made by posting a notice on a post or tree at or near the point of diversion. In some instances a copy of the notice was filed at the court-house of the county in which the appropriation was made, and the appropriation thus became a matter of record. Most of these placer workings have been abandoned, and the water rights in such cases have lapsed from non-use. In this way the records show a large number of appropriations of water which are no longer valid, but which will require careful investigation to separate from those remaining in full force and effect.

The former state laws authorized appropriations of water in the manner described, and the general custom of the country permitted appropriators to place on record such claims to the water-supply as they deemed advisable. The natural tendency was to make the claim large enough to cover all possible requirements, and in most cases greater than there was any expectation of using. This resulted in many cases in absurd and speculative claims, and the records show numerous instances where each of a number of claims to water of a stream, filed in accordance with the former statutes, involved a larger quantity of water than had ever flowed in it, even during flood periods. One provision of the former statutes permitted the acquirement of a water right by usage, and an appropriator under such circumstances was entitled to the enjoyment of such a quantity of water as he actually applied to beneficial use. Such water rights, acquired under the old water laws, as have been kept alive, are recognized as valid and of full force. The keeping alive of a water right consisted in making beneficial use of the water claimed during a portion, at least, of each year, and failure to use the water for a period of two years constituted abandonment.

In 1905 South Dakota adopted a code of water laws providing for the adjudication of existing rights and the complete public control of the water in the future. The office of state engineer was created, and the engineer was given general supervision of the waters of the state and of the measurement and application thereof. This law was amended and reenacted in 1907 so as to make it applicable to all beneficial uses of water without limiting its application to irrigation alone.

The previous state laws, as has been stated, provided for posting and filing notices, as did the laws of other states, and the state engineer has secured from the county officers copies of all such notices. The records do not show what was done under these notices, but the state engineer, in making hydrographic surveys, determines their status. Under the present State Water Code the state engineer is empowered to make all necessary general rules and regulations to carry into effect the duties devolving upon his office.

The state engineer is authorized to make hydrographic surveys of the various stream systems of the state, beginning with those most used for irrigation. These surveys comprise a measurement of the stream channel and also of important tributaries. All irrigation ditches along the stream are surveyed, their capacity determined, and the number of acres of land irrigated under them ascertained. It is not practicable to make stream gagings in connection with these hydrographic surveys on account of the short time available for this purpose. In many cases, however, the streams have been gaged by engineers of the U. S. Reclamation Service and these measurements of flow furnish excellent data concerning the amount of water available for use in the stream. Upon the completion of the hydrographic survey of a stream system, therefore, the state engineer is in a position to define existing rights to the use of the water, and also to determine if there is any water available for new water rights on that stream.

An applicant for the right to appropriate water must make application to the state engineer for a permit, furnishing all the data necessary for the proper description and limitation of the rights applied for, together with maps, plans and specifications such as may be necessary to show the method and practicability of the proposed construction and the ability of the applicant to complete the same. These maps, plans and specifications are to be filed in duplicate, one copy to be retained in the office of the state engineer and the other returned to the applicant. Notice of application must be published in some newspaper of general circulation in the stream system and a date is set for a hearing by the state engineer on the application. The engineer may reject applications if there is no unappropriated water in the sources of supply or if, in his opinion, their approval would be contrary to the public interest; but any applicant may appeal from such decision to the court. An approved application becomes a permit and, in his approval, the state engineer must state the time within which the construction must be completed, not exceeding five years, and the time within which the water must be applied to beneficial use, not exceeding four years from the date of completion. It is the duty of the state engineer to inspect all diversion works to determine their capacity, safety and efficiency, and to require all such works to conform to standards of safety. In cases where canals supply water to the lands of others than the owners of the canals, the engineer is authorized to fix the rates for carrying and delivering the water.

General Considerations.

I desire to take this opportunity to recommend the enactment of uniform water laws by the states in which irrigation is an established practice. It is a well-known fact that some of the western states are operating under water codes that were in use in the early days when conditions were entirely different from those prevailing at the present time. The control and the scientific application of water to land are better understood now than in pioneer days, and methods of appropriation should conform to modern practice. The experience gained during long years of irrigation work should be utilized in framing our water laws.

The value of a central state authority for administering water laws should be recognized and the technical knowledge and skill of the state engineer should be called upon to decide questions relating to the use and duty of water. The work of the state engineer is administrative rather than judicial. He is also required to perform duties of a technical nature in the way of measuring stream flow, supervising the construction of dams and diversion works and determining the size and capacity of ditches and canals.

A splendid opportunity is open to him for doing educational work in encouraging the economical use of water for irrigation. The common tendency to over-irrigate is deplored by all who are interested in the growth and progress of irrigation work. The state engineer is in a position to observe the duty of water on various kinds of soil in his state and to determine what is the proper amount to use in maturing crops.

*Slightly Condensed from address delivered at the Eighteenth National Irrigation Congress, Pueblo, Colo., Sept. 27, 1910.

†State Engineer of South Dakota, Pierre, S. Dak.

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We recall no act of the present Administration which will probably result in greater public benefit, and which deserves more hearty approbation by the business community than the effective indictment, arrest and imprisonment of some of the prominent concerns in New York City which have been selling worthless stocks to innocent investors.

It is a wonder that the swindlers who have been conducting enterprises of this sort have been allowed to carry on their business for many years almost unmolested. Postmaster-General Hitchcock is quoted as estimating that more than $100,000,000 has been filched from the pockets of the American people by stock-selling swindlers during the past five years. He is probably well within the mark. It is stated that, in the course of a few hours, after the Burr brothers were arrested until the news of the arrest was spread abroad through the newspapers, remittances were received, at their offices aggregating over $25,000.

As most of our readers know, the business of swindling the public by the sale of worthless stocks, bonds, mortgages, lands, etc., is carried on all over the country. That it is engaged in so openly is not due to any lack of statutes making it criminal and punishable, but to the fact that the state and national officers responsible for the enforcement of the laws have been almost criminally derelict in their duties. As a result of the neglect of these officers to prosecute and punish those engaged in these stock-selling swindles, a great many people with more or less pretentions to honesty have allowed their names to be used in connection with them, in one way or another. In this way some of these concerns have been able to obtain a semi-respectability which has aided them to fleece the public.

We pride ourselves as a nation on having wiped out such forms of gambling as the lottery, which still flourishes under protection of law in most countries; but it is an open question whether such stock-swindling schemes as the federal authorities are now proceeding against are not a worse fraud upon the public than any lottery. A lottery is at least open and above-board. The purchaser of a lottery ticket knows he is engaging in a pure gamble; but these stock swindlers do business under the pretense of being an honest and legitimate enterprise. They delude innocent investors all over the country into confiding to them their hard-earned savings. In this way they actually discourage habits of frugality and thrift.

Again, these concerns, which advertise that they will pay enormous dividends to investors and later defraud them of their money, cause the investing public to distrust honest business enterprises. The man who has an honest, legitimate proposition, which he desires to finance to-day on any considerable scale, has practically no recourse but to deal with the bond-selling concerns which make financing their business, and which exact a pretty heavy commission for such financing. The offering of stock directly to the public in any new enterprise offering reasonable profits has been given such a black eye by the advertising of stock-selling swindlers that it is practically impossible to finance a legitimate enterprise in that way at the present day.

It is not a good thing to perpetuate the monopoly of the investment business which the bond houses now hold. It ought to be possible for a railway or a manufacturing corporation to offer its stocks and bonds directly to the public without incurring the suspicion of dishonesty which now inevitably attaches to the advertising of stock.

Further than this, the many millions of money now lost in these swindles ought to be available for investment in legitimate enterprises, and may be if the campaign against the stock swindlers is continued.

Surely, therefore, Postmaster-General Hitchcock deserves the approbation of the business community for his fearless and efficient work in prosecuting the conductors of fraudulent enterprises.

In all comparisons of the relative economy of water and rail transportation, care should be taken to make allowance for the greater risk involved in transportation by water. With all the improvements in vessels, in channels and in guiding and warning signals, there yet remains in all transportation by water a risk of loss far greater than attends transportation by rail.

It is likely that the risk in water transport is greater in the case of coastwise navigation than in either deep sea sailing or transport on inland waters. A vessel sailing in coast waters is dependent for safety on the fidelity and accurate knowledge of a single man, the pilot. However closely the pilot may study his charts and however carefully he may obey them, there is always a chance in shallow waters that some obstruction may have been missed by the hydrographic survey when made by the ordinary method of sounding. Many shoals and reefs have been discovered only when the cause of some disastrous wreck. A notable illustration of this was the grounding of the U. S. Cruiser "Brooklyn" in Buzzards Bay, eight years ago.

During the season of 1895 a careful detailed survey was made of Buzzards Bay on the southern coast of Massachusetts. Sounding lines were run at 50 and 100 meter intervals; 91,000 soundings were recorded on a single sheet. The finished chart was regarded as an excellent example of careful, accurate and dependable work. In 1902, however, the U. S. Cruiser "Brooklyn," in passing through a portion of this surveyed area, in Buzzards Bay, struck upon a rock which was later found to have but 18 ft. of water over it. The least depth found by the survey anywhere in this vicinity was 31 ft., while the soundings as a whole indicated a level bottom at 36 ft. This rock is now shown on the charts as "Brooklyn Rock."

Other instances might be cited in proof of the proposition that a method of hydrographic surveying which will verify least depths over an entire area and not leave a percentage of uncertainty such as always attends line surveyings is a boon to navigators.

Such a method is described in detail elsewhere in this issue. This method, surveying with a wire drag, has now been used by the U. S. Coast & Geodetic Survey until an area of 325 sq. miles has been covered. In this area there have been discovered no less than 1,500 shoal spots having less depth than that indicated by the existing charts. At least one-fourth of these were so located as to be dangerous to navigation. We need hardly add that the area thus covered is only a small part of what ought to be covered to promote the security of transport by water.

Experiments in briquetting blast-furnace flue dust have been carried on in this country since 1896, but have not been so successful as to encourage general use on a commercial scale. The prospect of a diminishing supply of high-grade iron ore, however, with the accompanying necessity of a greater use of low-grade ores and "concentrates," should give a fresh impulse to the briquetting movement. In briquetting flue dust, the only object is to make it available for use in the furnace and thereby recover the iron which would otherwise be wasted. In briquetting fine ores, which could possibly be used without briquetting, the object is to obtain a more complete reduction of the ore, to prevent scaffolding and to reduce the quantity—and therefore the expense of handling—of the flue dust carried out of the furnace.

The greater scarcity in Europe of high-grade iron ore has probably had a great deal to do with the stronger practical interest shown there in ore briquetting. In this country, the reserve of iron ore is such that until recently an ample supply of the highest grade has been easily available. It is estimated, however, by Mr. E. C. Harder in "Mineral Resources" for the year 1908, published by the U. S. Geological Survey, that "before 1940 the production of iron ore must already have reached a maximum and begun to decline, and a very large use must be made of low-grade ores not now classed as available." This decline in the production of high-grade ores must tend to stimulate the interest in briquetting.

A description of the principal methods of ore briquetting which have been used in Europe is given elsewhere in this issue, together with some account of the measure of success obtained and the conditions necessary to make the briquetting of iron ore commercially profitable.

A Revolutionary Improvement in Sewage Treatment.

There are different ways of estimating the success of a sewage-disposal plant. Chemical and bacteriological standards may be invoked in varied modifications. The scientific investigator usually relies on such analyses in forming his judgment. The ordinary man, however, who visits a sewage-treating works applies the very simple test of smell. If the process creates a stench, or if the effluent creates nuisances elsewhere, he deems the process unsuccessful. And the judgments rendered on this basis are ultimately the deciding ones, for it is the people at large who pay for such works and who render the ultimate verdict of approval or condemnation.

Most existing sewage-disposal plants are damned by their smell. From the sanitarian's viewpoint, they are (most of them) successful, because they yield an effluent of reduced putrefactive power and reduced disease-carrying capacity, which can be discharged into a stream without causing offense. The scientific sanitarians also aver that bad smells are not of themselves injurious to health. Hence, they say, these sanitary results are well worth buying at the cost of a little smell. There is, however, more or less popular protest against this doctrine. Indeed, the question may be raised whether the sanitary disposal of sewage has first and last any other object than the abolition of bad smell. In so far then, as a sewage-treating process produces bad odors, it fails of the object it is designed to accomplish.

It is a fact that testimony varies widely as to the amount of bad odor from existing sewage-

purification works. There have been reports almost good enough to warrant locating sewage-purification works in the middle of a city. More often the expert examining a sewage station has conceded that some odors were created, odors not necessarily offensive to the expert nose of the sewerage specialist, but probably unpleasant to sensitive persons. It is safe to say that the best sewage-purification plants, examined under the most favorable conditions, spread no bad odor farther than a short distance beyond their own limits, and that the poorest plants, at their worst times, are rank nuisances to a great area of surrounding country.

In the annual report of the Chief Engineer to the Board of Estimate and Apportionment of New York City, for 1909, we find the results of an investigation of what is perhaps the most recent and up-to-date sewage disposal plant in the United States: the installation of sprinkling sewage filters at Columbus, Ohio. As some of our readers know, there has been much agitation in New York during the past two or three years looking to the purification of all sewage before its discharge into any stream. Those conducting this agitation appear to have the idea that it is possible to purify the sewage of any city regardless of its conditions, and to do so without creating any nuisance. The Chief Engineer of the New York Board of Estimate, Mr. Nelson P. Lewis, M. Am. Soc. C. E., therefore, sent an engineer, Mr. John E. Hill, to investigate the Columbus plant. We quote as follows from Mr. Hill's report:

> Under your instructions I spent two days investigating the area of possible nuisance connected with the odors emanating from the septic tanks and sprinkling filters of the Columbus sewage purification works. . . . While the season of the year and the weather conditions during my visit were unfavorable for the obtainment of the most definite and conclusive results, the thermometer varying between 32° and 71° and the weather being intermittently rainy, still the fact that a strong wind was blowing almost continually was advantageous. . . . I caught the odor from the purification works, suddenly and strong, at a distance of about three-quarters of a mile from the works. There was no doubt about the character and offensiveness of this odor. It was characteristic of the septic tank and for the moment was nauseating. For the distance of three-eighths of a mile this odor was dully sickening; from this point it decreased in intensity and intolerability until a point to the windward of the septic tanks and in the vicinity of the filter beds was reached, where it was not so intensely offensive. . . . The universal testimony [of various persons] was to the effect that under certain conditions intolerable odors were appreciable to the limit of from three-quarters of a mile to one and a half miles from the works, and that the plant might honestly be considered a nuisance up to these limits.

Undoubtedly the Columbus plant represents the latest and best practise in sewage purification. It is said that the Columbus sewage treated in the filters is particularly bad smelling because of many defects in the city's sewer system, which allow the sewage to stand and putrefy at various points before it reaches the sewage works. But the sewerage system of practically every American city is also more or less imperfect. The Columbus results simply mean that a sewage filter plant must be put far in the outskirts of a city and in a location where real estate is worth very little, or it is likely to cause great property damage.

Under these conditions, it is difficult to overestimate the importance of any method of sewage treatment which would be free from offensive odors. Were any such method of treatment brought forward from an unknown source, claims for it would be naturally met with great skepticism. When, however, a sanitarian with the reputation of Mr. Rudolph Hering comes forward to vouch for a new system, it certainly deserves the careful attention of the engineering profession.

Mr. Hering declares that the Imhoff tank, a recent German invention for sewage treatment, makes possible the purification of sewage *without offensive odor*. Elsewhere in this issue we print a paper on the Imhoff tank written by Mr. Charles Saville, formerly connected with the Massachusetts State Board of Health, and now an assistant of Mr. Imhoff's. Mr. Hering, in an introduction to Mr. Saville's paper, explains the great importance of Mr. Imhoff's work. Under Mr. Hering's advice, this process of sewage treatment is already being tried in several American cities and is to be adopted on a large scale at Atlanta, Ga.

Can the "Principles of Scientific Management" Be Applied to Railway Operation?

The long drawn out proceedings before the Interstate Commerce Commission in the matter of the proposed increase of railway freight rates were made interesting last week by the proposal, on the part of the counsel for an Association of New England shippers, to show the railways of the United States how to save a million dollars a day in operating expenses.

Mr. Louis D. Brandeis, of Boston, attorney for the shippers, in a well worded address, set forth his belief that there were great possibilities of economy still unrealized in railway operations. He declared that by applying what he termed "the principles of scientific management" to the railway business, operating expenses could be so reduced that there would not only be no need to increase the present rates of fare and freight, but additions could be made to dividends and improvements could be made in the service which would make happy both the railway stockholder and the traveling public.

We print below, as a matter of record, the substance of Mr. Brandeis' opening address.* The questions he raises are undoubtedly of great importance, particularly at the present juncture, when we are about to put in practice the principle that railway rates must be limited to a scale which will return a fair income on the capital actually invested.

It has long been foreseen that, when this principle is established in the operation of any public utility, a large part of the incentive to economical and efficient operation is taken away. If a railway company saves money by conducting its operations with especial efficiency and economy, and the only result of this economy is to bring about a reduction in the rates for carrying passengers and freight, it is self-evident that a chief incentive to saving is removed. Conversely, a railway may be so mismanaged that money will be wasted in any one of the hundred ways by which a railway's expense account may be swollen. If those responsible for such mismanagement can simply raise freight rates so that the net earnings will be maintained notwithstanding the increased expense, then we shall not only see an end to economy in the railway business but we shall open a wide door to all sorts of extravagance and graft, the cost of which will fall on the public.

It is entirely proper, therefore, for the public to enquire whether railways are operated efficiently. The railways are now asking permission to raise their rates because their expenses are so high. It is pertinent, therefore, to inquire whether operating expenses are kept down to the point that they ought to be.

In discussing this question, Mr. Brandeis disclaims any criticism on the competence and ability of railway officers in general, and admits that they are probably conducting their business as well on the average as the ordinary private business is conducted. His claim for huge possible savings he bases on the idea that, by applying so-called "scientific management," or, as it is sometimes termed, "efficiency engineering," to railway operating problems, the cost of railway operation could be enormously reduced.

In order to point out the fallacy which underlies this claim of Mr. Brandeis and the "efficiency experts" whom he placed upon the witness-stand, we venture to make a suggestion to them. Our suggestion is that they attempt to apply "scientific management" or "efficiency engineering" to their own household servants. After they have tried this for six months to a year, we hope they will come back and report to the Interstate Commerce Commission how much they have saved in their household operating expenses.

Mr. Brandeis has made the error of treating the business of railway transportation as if it were a manufacturing industry. But running a railway is not like manufacturing; it is more like keeping house.

For example, one of the largest items in the operating expenses on every great railway line is the salaries of its station agents. Suppose one of Mr. Brandeis' efficiency experts should go to a country railway station and study the movements of the station agent throughout the 24 hours of the day. Suppose he could show him how to sell tickets with one hand, while he made out freight way bills with the other. We doubt very much whether the agent would be any happier or better contented with his job after he had been thoroughly "efficientized"; and as the railway must have a whole man at each station, and cannot get its business done with 5/16ths or 27/32ds or any other fraction of a man, there is no place that we can see where any saving would result in the railway pay-roll.

The case of the station agent at a country station is not exceptional but typical of railway service. Take another very large class of railway servants—the engineers and firemen on locomotives. These men are already performing feats of efficiency engineering by doing several things simultaneously, such as watching for signals, attending to injectors and graduating the throttle. There is no chance for Mr. Brandeis's efficiency experts to save anything in engine-runners or firemen's wages; and, as for teaching the one how to handle his machine more economically, and the other how to fire coal so as to save fuel and prevent smoke, the railways already have, and have had for many

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*FROM THE OPENING STATEMENT OF MR. LOUIS D. BRANDEIS BEFORE THE INTERSTATE COMMERCE COMMISSION.

We shall offer evidence tending to show that even if the railroads need additional net income, it should be secured through greater efficiency and economy of operation instead of resorting to the dangerous expedient of raising freight rates.

The eminent railroad presidents who testified before your commission have declared that further economies are practically unobtainable. Thus President McCrea, of the Pennsylvania, said:

So far as concerns economies which will result from reduction in grades, increased hauling capacity of locomotives, and increased capacity of cars, the companies are to-day already practically deriving the full benefit from those which are possible in this direction due to expenditures heretofore made that have practically completed our great reductions and have probably reached the maximum size for our cars and engines.

Again, when I asked him: You stated that you thought the limit of increase in efficiency and resultant economy was practically reached, Mr. McCrea answered, I did, sir. And he added also: There is no reason in my judgment for expecting that further increase of gross earnings will tend materially to reduce this operating ratio except to the extent to which increased rates of freight will tend to do this.

To these declarations of despair involving a vicious circle of ever-increasing freight rates and ever-increasing cost of living, we oppose the gospel of hope. As an alternative to the practice of combining to raise rates and hence to increase prices, we offer cooperation to reduce costs and hence to lower prices. This can be done through the introduction of scientific management, resulting in greater efficiency and greater economy in operation. In so saying, we offer a constructive policy of management, not personal criticism of those to whom the management of railroads is now entrusted.

Undoubtedly there exists among railroad men the same difference in the degree of competency as in men engaged in other lines of business. Their competency and ability is no less, and is perhaps no greater than that existing in the private industries; and it is no doubt true that railroad managers have been subjected to certain strains upon competency, from which managers of most private businesses are ordinarily free.

For in railroading the stimulus of competition has been largely removed, in many of the railroad systems the increase in size has created burdens greater than human capacity can carry, and frequently erratic interference with the management by the financial interests of Wall Street, as it is commonly expressed, has greatly increased the difficulty of those charged with the operation of the properties, and has often prevented effective and economic operation.

We shall show you how scientific management, when applied to the simple operation of loading a railroad car with pig iron, increased the performance of the individual worker from 12½ to 47 tons; how, when applied to shoveling coal it doubled or trebled the performance of the shoveler; how, when applied to the operations of a machine shop, it developed, in certain operations, increases ranging from 400 to 1,800%; how, when applied to brick laying, the day's accomplishment rose from 1,000 to 2,700 brick.

We shall show that the principles of scientific management are general in their application; that they can be introduced into practically all businesses and all departments of any business; that they have been successfully applied in private competitive businesses like machine shops and factories, steel works and paper mills, cotton mills and shoe shops, in bleacheries and dye works, in printing and in bookbinding, in lithographic establishments, in the manufacture of typewriters and optical instruments, in construction and engineering work and in activities not commonly classed as business; and that recently, to some extent, they have been introduced by the United States Government into the manufacturing department of the army.

We shall show also that, to a very slight extent, these principles of scientific management have been applied in railroading, and that, in so far as they have been so applied, they have obtained valuable results similar to those obtained in private competitive businesses.

And finally, we propose to show the huge field for the application of scientific management in American railroad operation and the rich fruit in economies and improved service which may be expected to result, economies which have been estimated as aggregating in amount more than a million dollars a day.

years, Traveling Engineers at work engaged upon this very task.

But the man with the efficiency mania constantly refers to the railway repair shops and tells us how, by proper cost keeping and proper systems of paying for labor, he could bring down the cost of locomotive repairs to an infinitesimal figure. The true answer to this argument, however, is, again, that running a railway repair shop is not manufacturing; it is keeping house.

It is well known that a railway company cannot, save under exceptional conditions, manufacture cars or locomotives at anything like the low cost that the work can be done for by one of the large manufacturing concerns which make this business their specialty. The reasons for this are so obvious that they need hardly be entered into. The same rule applies here that applies to hundreds of other lines of business. It is not possible to operate a concern of enormous magnitude, branching out into a multitude of different lines, with anything like the economy and efficiency that can be obtained in a concern of moderate size, devoting itself to one specialty and bringing to bear upon that a maximum of intelligence and initiative.

It is not a *new* idea, either, that the railways might operate their repair shops more economically. As a matter of fact, many railway officers have for years been working on the problem of introducing in their repair shops the piece-work system, the premium system and other advanced methods of paying for labor on the basis of its efficiency. Many such experiments have shown good results; others have succeeded in strangling the business with red tape, and the resulting saving has appeared on the wrong side of the ledger.

The fact is that "efficiency engineering" is a splendid thing, provided it is applied with the aid of common sense and by a *really efficient* "efficiency engineer."

Mr. Brandeis's brilliant critique of American railway operations, and his proposal to save a million dollars a day, or substantially 18% of the present daily expense bill of American railways, is based on a fallacy. Yet there is a modicum of truth underlying it.

We agree with Mr. Brandeis that the end of economies in railway operations has not been reached, as has been pointed out in these columns at various times, nor is it likely to be. The great difficulty with railway operations at present is that the men in charge are so overburdened with routine matters that they have as a rule no time or energy to spare for the study of new means and methods of saving over those which have been long in use.

For, notwithstanding all the remarkable achievements in economic transportation which our railways have effected, there are still many directions in which further improvement is possible. These opportunities for further improvement need to be studied by real efficiency engineers; but they should be men who are practically experienced in actual railway operations; who know what can be done and what has been done; who know the directions in which improvement is possible, and who knew the paths which have been tried again and again only to find the sign "No thoroughfare" posted at the end.

There ought to be a large field for the employment of railway officers of experience and initiative in such consulting engineering work.

LETTERS TO THE EDITOR.

The Physical Meaning of Entropy.

Sir: Professor Reeve's criticism of my article on "The Physical Meaning of Entropy" in your Oct. 6 issue, and Professor Wm. Kent's reply thereto in your Oct. 27 issue, have just come to my notice.

I was pleased to note that Prof. Kent has pointed out Prof. Reeve's evident error in declaring that my definition "makes entropy synonymous with heat." This criticism is evidently due to a hasty reading of the definition, for to interpret entropy as "unavoidable waste per degree of temperature," to mean that it is waste or rejected heat, is about as logical as to conclude that because velocity is distance passed over per unit of time it must therefore be synonymous with distance. The phrase "per unit of some property" unquestionably designates relativity and as commonly used can only mean that the subject is a ratio, that is, a quotient of one quantity divided by another. I note that, through a stenographic or typographical error, Prof. F. Kent appears to change the term "unavoidable waste" to "avoidable waste" in restating my definition of entropy.

Prof. Reeve also states that my definition "treats the Carnot cycle as if it were a single simple process, etc." A careful reading of my article will disclose that my definition is based not on the Carnot cycle, but on the Carnot efficiency, which is generally accepted as the ultimate efficiency obtainable by using any heat engine employing any cycle whatever.

Prof. Reeve accuses me of advancing conclusions which I have not advanced and then proceeds to state that these are "sheer misstatements of physical fact."

Relative to the statement in my article that the definition advanced by me harmonizes with two somewhat different definitions previously advanced—one attributed to Clausius and another by Mr. James Swinburne, Prof. Reeve writes as follows:

> But the sole task undertaken by Mr. Swinburne . . . has been to recall modern pedagogs to the strict definition of entropy originally attributed to Clausius. Therefore there can be no distinction between Swinburne and Clausius.

The definition attributed to Clausius and to which I refer is as follows:

> Entropy is that portion of the intrinsic energy of a system which cannot be converted into work by even a perfect engine.

It has been denied that Clausius ever advanced this definition, and as it stands it is manifestly incorrect. But if qualified to read,

> Entropy multiplied by the absolute temperature at which heat may be rejected gives that portion of the change of intrinsic energy of a system, etc,

the definition holds. This definition treats of entropy from a somewhat different point of view from the definition quoted above. The writer makes no claim that Clausius advanced this definition; it was attributed to him in one of the English magazines. The definition advanced by Mr. Swinburne to which I refer, and which may be found in his book "Entropy" is as follows:

> Increase of entropy is a quantity which, when multiplied by the lowest available temperature gives the incurred waste.

Both of these definitions were brought out by Mr. Swinburne's presidential address before the British Institution of Electrical Engineers in 1902 and much heated discussion followed, in which such eminent men as Sir Oliver Lodge, Prof. Poincare and Prof. Max Planck participated. Notwithstanding this discussion and the prominence of its participants, for some reason, a commonly acceptable definition of entropy seems to have still remained a desideratum. One has but to review the definitions of this term in the various text books on thermodynamics and physics and to question technically trained engineers as to its meaning to appreciate this fact. In this connection, I can do no better than to quote Prof. Reeve's own words from the Harvard Engineering Journal for 1908:

> Its results (referring to the discussion mentioned above), so far as visible in the latter contributions to the controversy were to leave the question exactly where it started, with no one converted to new ideas, and with entropy still undefined in any adequate sense.

I am pleased to note that no adverse criticism of the mathematical proof for my definition has come forth; for any definition must stand or fall with the proof upon which it is based. It has been pointed out that though entropy is represented by $\int_0^{Q_1} \frac{dQ}{T}$ it is equivalent to the quotient of unavoidable waste divided by temperature at rejection, i. e., $\frac{L}{To}$. There can be no mystery about this latter expression.

The purpose of my article was not to attempt to explain entropy as one would attempt to explain heat or matter, but to point out the physical significance of this term as it concerns the engineer, who rightly declines to employ any term or conception in his work which is vague and mysterious.

It may be of interest to point out, as has been shown by the problems appended to my article, that an understanding of entropy from the point of view advanced enables one to calculate the ideal efficiencies of steam and other heat engines without resorting to the Rankine cycle or to a temperature-entropy diagram.

Respectfully yours,

A. L. Menzin.

No. 823 Sheldon Bldg., San Francisco, Cal., Nov. 9, 1910.

Prof. Kent's Entropy.

Sir: If memory serves aright, the conversation of fifteen years ago, recalled so pleasantly by Professor Kent in your issue of Oct. 27, was aroused by his statement before the Society for the Promotion of Engineering Education that an understanding of the term "mass" was unnecessary in learning mechanics.

In one sense this statement is quite true. All of the problems of the applied mechanics of engineering can be solved by the use of W/g instead of M in the equations. It is also true that all manner of useful electrical machinery can be built without a question of what is electricity, or what a "line of force." It is also true that Carnot discovered his fundamental thermodynamic principle without knowledge even as to whether heat were a substance or a form of energy.

It is similarly true that the mathematical science of thermo-dynamics can be completely mastered without further concept of entropy than its bare mathematical definition of quantity. My students were always given freedom to confine themselves to this bald aspect of the study if they chose.

It seems scarcely necessary to argue, however, that all of these sciences are capable of far richer fruition than this mere solution of mathematical problems. The understanding is to be broadened by their discussion, and the conduct of life guided by their light. Neither can be accomplished without such queries as what is mass, what is force, what is heat, etc.

But of more immediate importance than these generalizations is the duty of the teacher not to create confusion in the student's mind. If the sciences are to be taught woodenly, such statements as that "mechanical action is based upon mass" and that "heat is a mode of mechanical energy" must be omitted. To teach mechanics mechanically, in terms of W/g only, is consistent enough, even if short-sighted. But to present the symbol M to the student without explaining the reason for distinguishing it from W/g, and its fundamental import in the science, is more than short-sighted; it is actively confusing, and should be warmly condemned.

Similarly, the practical design of heat-engines may be taught without any mention of the mechanical aspect of heat. But if this policy is adopted it must be adhered to. To teach that heat is a sort of mechanical motion, without explaining what are the laws of motion, is obviously confusing and should be condemned.

Although Professor Kent seems to think that the writer has gotten far afield in applying the laws of interstellar mechanics to thermal activity, cannot he see that the mere use of such a phrase as "heat is a form of molecular motion," if it accomplishes anything at all, raises in the student's mind a picture of every hot body as a system of "free" mechanical projectiles—that is, a vast interstellar or intermolecular space occupied by a myriad of tiny solar systems, comets, etc., all guided by Newton's laws? What else mechanical can a hot body be? To present to the student this picture of thermal dynamics and then to leave him stranded on the shoals of an insufficient terrestrial mechanics is certainly confusing.

Similarly, to teach that entropy is the thing which drives every piston and turbine-blade in existence, as one must who treats of entropy at all, yet that it has only a mathematical phantom existence, is confusing, to say the least. To teach that entropy is nothing more than dQ/T, when entropy is active in nature only when this function is zero, is certainly confusing. It amounts to saying that all of the energies of man and nature are embodied in nothing at all. But worse than this, to teach that entropy is a function of dQ/T without even defining the symbols—for none of the orthodox authorities stop to tell us what dQ is or is not—is confusing and mathematically wrong.

In short, to be content to know a thing only by its measure, to study a peck of wheat merely as so many cubic inches, good for so many pounds of flour and bread, with scorn for any enquiry as to what the grains of wheat themselves may be, what the nature of their life, what the source of their chemical energy, what their bonds of similarity with all other vegetation—this is a policy followed by the majority of succesful wheat-growers, sellers, millers and bakers, the world over. It is none the less a policy which every center of learning should stand firmly to discountenance.

On April 4 last the Engineering News reviewed Mr. R. T. Crane's iconoclastic book, "The Utility of Higher Schooling," and on May 12 Dr. G. F. Swain's address "Limitations of Efficiency in Engineering Education." Editorially the News disagreed warmly with Mr. Crane and upheld Dr. Swain, the key-note of whose words was a call for the inculcation in the young engineer of an "ability to think."

The position of Dr. Swain and Engineering News seems incontrovertible; yet it stands opposed to the entire trend of the times. The demand of the day, from employers, parents and older students alike, is increasingly for an encyclopedic equipment of disjointed facts—not the broad facts of world-knowledge, sure to be applicable to the unknown problems of a generation hence, when these young men will be fighting their world-battles and our problems have been forgotten—but facts

of the Mr. Gradgrind sort, aplicable to the narrow tasks of today only and immediately negotiable for a job.

If Dr. Swain is right, then there is no finer opportunity for his sort of education than in the study of entropy; for the entropic condition prevails in as many sorts of energetic action as any physical fundament, and it constitutes an undeveloped field for study. The "ability to think" is an ability to trace cause and effect, and entropy enters into all physical cause and effect. The bare mathematical treatment of entropy as a thing peculiar to heat only, making of thermodynamics a science isolated from all others, may have been timely before Count Rumerford measured the heat of cannon-boring, more than a century ago. But since the work of Carnot, Grove, Mayer, Helmholtz, Joule and Kelvin it is a crass anachronism. It shuts tight before the student's eyes that beautiful vista of the unity between heat and work—not to mention that between heat and chemical and electrical energies, now as well established as was that between heat and work 50 years ago.

Entropy is mere weight of organization of mass. Organization is the fetich of these populous, intricate days. The student knows better than his teacher the weight of organization in work-performance. In athletics, in fraternities, etc., the worth of organization is obvious. He knows instinctively that a body of unorganized boys, inert, blundering and lifeless, may be transformed into a lively, skilful and powerful group, potential for all sorts of kinetic energy, by mere organization. Mr. Deland, the football authority, attributes 75% of success in that line to the coaches and their work—organization—and but 20% to the personal skill and energy of the individual players themselves. This is not the era of individuals, but of communities. Modern, as contrasted with ancient, energies are those of organizations as contrasted with those of giant individuals. Among adults the classes who should appreciate these facts best are the military, industrial and political leaders.

Entropy is mere weight of organization of mass. A cold unentropic molecule is like a huddled, inert, unorganized mob—an undivided, non-interacting unit. It is like the moon—hard, tideless and lifeless. It is like an Oriental factory, where every man must do just what all the rest do.

This solid, stolid unity of the molecule is broken up by the advent of impact, friction or thermal conduction, setting the fragments into energetic reaction with each other. Separation, differentiation, specialization, action and reaction set in. This is the isotherm, dQ.

The greater this entropic condition of organization the greater becomes the potentiality of the mass for work-performance. Work is performed by the expenditure of temperature (intensity of individual activity) while the organization, or entropy, remains unchanged. This is the adiabatic, dW.

The preliminary weeks of coaching are to the football team what the isothermal evaporation is to the molecule of steam, or chemical dissociation to the molecule of gunpowder. The quick adiabatic development of energy is as the final game upon the field.

These two processes (1) the preparation or annulment of organization or entropy, and (2) the expenditure or gain of individual activity, or temperature, in work-performance by its aid, cover all thermodynamic, all mechanical, all chemical, all electrical and all social energies, however apparently complicated. This fundamental aspect of all the energetic sciences together appears to me essentially more simple and useful than the bare mathematical statement of each in isolation. I cannot understand the reluctance to its use.

Sidney A. Reeve.

20 Central Avenue, Tompkinsville, Staten Island, New York City. Nov. 2, 1910.

Checking the Spread of Forest Fires by Broad Fire Lanes.

Sir: The theory, mentioned in your columns both editorially and otherwise (particularly in your issue of Oct. 27) of protecting our forest reserves from fires by clearing so-called lanes, is indeed interesting.

Remember that our Western reserves contain thousands and thousands of square miles of area and the expense of protection by such methods is enormous when compared with the expense of protecting the comparatively small European forests mentioned in previous article.

Of course this method can be used to advantage if careful study is made beforehand and the necessary appropriations are forthcoming without delay.

Probably the best and cheapest way of doing this would be to take advantage of the numerous rivers and streams found therein, and clear a certain width on each side. Much of the timber could then be cut into logs and would immediately have a commercial value, as it could be floated to a convenient place for rafting and then towed to the sawmills at, or near, salt water, on the western slopes, which are usually quite numerous. A great deal, however, of the entire lane area would have to be destroyed as it would be impossible to put it to commercial use in most cases.

The burning of the timber and brush should immediately follow the cutting, and those in charge should be sure that the appropriations were sufficient before cutting is commenced. Otherwise we would have large areas of fallen timber and dry brush that would be worse than useless for preventing the spreading of fires.

Very respectfully,

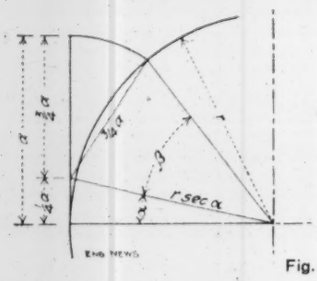
W. S. Wheeler.

Cristobal, Canal Zone, Panama, Nov. 6, 1910.

The Accuracy of an Approximate Method of Drawing an Arc of Definite Length.

Sir: In making drawings it is often necessary to lay off a circular arc of definite length, and any method of doing this which is both convenient and accurate is of considerable value. The method here described is not new, but it is extremely simple, and when used within proper limits it gives very accurate results. The purpose of this article is to show the degree of accuracy of the method for arcs of different lengths.

Referring to the diagram, Fig. 1, a is the length of arc required. A line is drawn tangent to the circle at the point from which the arc is to be measured, a point on the line at a distance $\frac{1}{4}\,a$ from the point of tangency is taken as a center, and an arc of radius $\frac{3}{4}\,a$ is drawn, intersecting the circle. The point of intersection is the end of the arc of the desired length.



$$\alpha = \tan^{-1}\frac{\frac{1}{4}a}{r} = \tan^{-1}\frac{a}{4r}$$

$$\cos\beta = \frac{r^2 + r^2\sec^2\alpha - \left(\frac{3}{4}\right)^2 a^2}{2r^2\sec\alpha}$$

$$= \frac{1}{2\sec\alpha} + \frac{1}{2}\sec\alpha - \frac{9}{32}\cdot\frac{a^2}{r^2\sec\alpha}$$

$$= \frac{\cos^2\alpha + 1}{2\cos\alpha} - \frac{9}{32}\cdot\frac{a^2}{r^2}\cos\alpha$$

Fig. 1.

a/r	Angle α.	Angle β.	α + β.	Arc.	Difference.	% of Error.
2	26° 33.90′	90° 0.0′	116° 33.90′	114° 35.49′	1° 58.41′	1.72
7/4	23° 37.76′	77° 36.03′	101° 13.79′	100° 16.06′	0° 57.73′	0.95
3/2	20° 33.36′	65° 49.05′	86° 22.41′	85° 56.62′	0° 25.79′	0.50
5/4	17° 21.24′	54° 26.02′	71° 47.26′	71° 37.18′	0° 10.08′	0.23
1	14° 2.18′	43° 18.83′	57° 21.01′	57° 17.75′	0° 3.26′	0.095
3/4	10° 37.18′	32° 21.89′	42° 59.07′	42° 58.31′	0° 0.76′	0.029
1/2	7° 7.50′	21° 31.46′	28° 38.96′	28° 38.87′	0° 0.09′	0.005

The table gives the results of these computations for various values of a, ranging from $\frac{1}{2}\,r$ to $2\,r$. For small values of a the method is very accurate, and indeed for arcs equal in length to the radius of the circle, the error is not greater than that which would be expected in the use of drawing instruments. For arcs of greater lengths, the error increases rapidly, as is shown graphically by the error curve, Fig. 2, and it is plain that the method is not adapted to such arcs unless they be subdivided.

The most common application of the method is for transferring linear measurements to the arc of a circle, as in drawing gear teeth and the like, but it is also useful in laying off an arc of a given number of degrees, first by a simple arithmetical process reducing the degrees to linear measurement on the circumference. It is worthy of note that in this case no protractor and no tables of angular functions are needed, nor need the center of the circle be accessible.

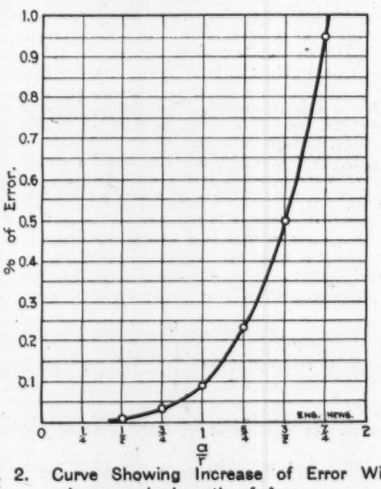


Fig. 2. Curve Showing Increase of Error With Increase in Length of Arc.

The true length of the arc required, expressed in degrees, is obtained by the formula:

$$\text{Arc} = \frac{a}{r} \times \frac{360}{2\pi},$$

r being the radius of the arc.

Yours truly,

Arthur H. Morse, Mechanical Engineer.

2305 Nelson Ave., Cincinnati, Ohio, Oct. 22, 1910.

Notes and Queries.

An error was made in our issue of Nov. 24, p. 562, in the article describing the Kinzie St. (Chicago) Drawbridge, in stating that contractors for the superstructure, the Toledo-Massillon Bridge Co., were of Cleveland, Ohio. This should have read Toledo, Ohio.

RAISING CONCRETE BRIDGES AFTER SETTLEMENT is a novel kind of work which was mentioned by Mr. O. E. Strehlow in a discussion of a paper on "Reinforced Concrete Trestles for Railways" (by Mr. C. H. Cartlidge) before the Western Society of Engineers and printed in the Society's "Journal" for October, 1910.

One case was a continuous slab built in place across the head race of the Oliver hydro-electric water power, at South Bend, Ind. It was 125 ft. long, with bents about 12 ft. c. to c. A washout undermined several of these piers and the bridge settled about 14 ins. The slab which settled with the piers was raised with jacks to proper grade. There was no indication that there had been any settlement and there was no crack in the slab.

The other case was an arch bridge, with about 70 ft. spans, at Jacksonville, Fla., where the piers were 8 ft. thick at the top. There was a settlement of about 12 ins. in one of the piers. Holes were drilled in the sides and ends of it; plugs and feathers were driven in, and the pier cracked in two; then jacks were installed and the adjacent arches were raised to proper grade. This was about four years ago and the jacks are still in place. After every freshet, as the pier settles still more, the jacks are operated and thus the bridge is kept level. The total settlement now is over 2 ft., but it is gradually decreasing. After it ceases, concrete will be placed in the space in the piers, and the bridge will then be safe and complete.

A PERIPHERAL SPEED OF 29,200 FT. PER MIN. was reached with a pulley recently tested by the Dodge Mfg. Co., Mishawaka, Ind.—a figure which is claimed to be the record for pulleys. While the common speed of ordinary iron and steel pulleys for mill and factory work is limited at about 6,000 ft. per min., a customer of this company desired a 46½-in. diameter pulley, with a 16-in. face and a 4-in. bore, to operate at about 736 r. p. m. or 9,000 ft. per min. This was for use on electrical machinery. When the pulley was built an exact duplicate was made to ascertain at what speed such a pulley would burst. The spiders were of cast iron and there were no metal rims, the spiders being fastened directly to the built-up wood rims. The pulley to be shipped was run for a time at 10,000 ft. per min., but the duplicate was fitted up to a small line shaft in a vacant room, where a strong barricade was erected to protect the observers against flying pieces when the pulley should burst. The test was made at the noon hour, when the main engine of the factory was available for variable speed. According to the test readings, an actual speed on the testing shaft of slightly over 2,400 r. p. m. was reached and without damage to the pulley. The diameter of the pulley was 46½ ins.; the actual rim speed was computed to be 29,200 ft. or 5.54 mi. per min. The test was not continued to destruction.

The Clark Quick-Dumping Steel Ore Car.*

By JAMES S. MARTIN.†

In the early part of 1909 the Clark Car Co. (organized in 1907) placed the first sample balanced-door dump car on the tracks of the Duluth, Missabe & Northern Ry. Mr. Charles H. Clark, President of the company, had developed the Summers ore car while engineer of the Summers Steel Car Co., and therefore understood the conditions to be met in the ore trade.

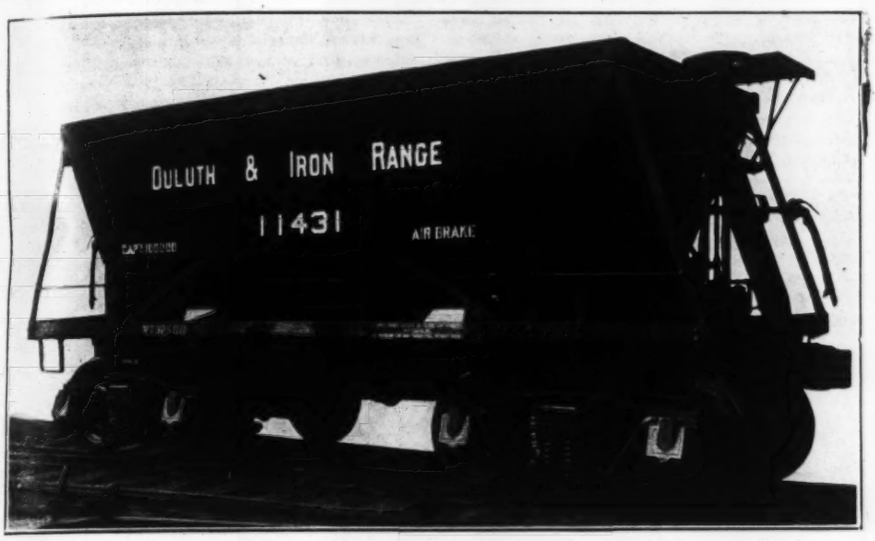


FIG. 1. STEEL 50-TON QUICK-DUMPING DROP-BOTTOM CAR FOR CARRYING IRON ORE; DULUTH & IRON RANGE RY.
(The Clark Car Co., Pittsburg, Pa.; Builders.)

In the spring of 1909, Mr. W. A. McGonagle, President of the Duluth, Missabe & Northern Ry., invited various car companies to enter dump cars for competitive tests on his road. Reference was made to these tests in Engineering News of Oct. 27, 1910, and a summary of the tests was included in the description of the Summers ore car, written by Mr. Frederic Schaefer, Engineer of the Summers Steel Car Co. The summary given in the accompanying table is taken directly from the reports of Mr. J. W. Kreitter, Superintendent of the railway, who was in charge of the work of making the tests.

Cars that were entered by railway companies have been omitted from the above as none of them were of recent design or quick operation. It will be seen that the Clark car No. 170 (which was the first of its kind ever built) showed up quite favorably with the rest of the cars. Particularly it should be noted in the relation of its performance to that of the Summers car No. 101, which was also a sample car. The Summers car had 50° end slopes and the Clark car had 45° end slopes. The Clark car met with an accident at the mines, after which its performance was not so good as it had been in the first few tests. It was withdrawn from the tests about Aug. 1; and on Sept. 9 Clark car No. 210 was entered. Comparison can be made between the performance of this car and the second and third Summers cars (Nos. 9,985 and 10,384). Mr. Schaefer's report of the tests (Engineering News, Oct. 27) does not mention the performance of Clark car No. 210. The above statement is made in order to include this car in the test reports, as it is the only type of ore car which the Clark Car Co. has offered for sale, and for which it has received orders. Fig. 1 shows one of the cars of this type for the Duluth & Iron Range Ry.

The Clark balanced door is now in the field of dump car design, and the performance of the cars of this type now being built for the Duluth, Missabe & Northern Ry., the Duluth & Iron Range Ry., and the Lake Superior & Ishpeming Ry., will be watched with considerable interest. The company has devoted 2½ years to investigation and experiment in handling ore, leading up to its present perfected design. The operation of the balanced doors is unique in that the center of gravity is not lowered in opening or closing, and consequently requires no mechanical traps in the form of reduction gears, chains, ratchets, etc., to enable one man to open or close the doors.

All of the newer ore cars have hopper openings ranging from 40 to 50 sq. ft. of area. To properly close such an opening under the weight of a load of ore requires steel doors weighing from 1,500 to 1,600 lbs. It is obvious that to lift these doors to closed position (after opening), with the power of one man, necessarily requires mechanical reduction of at least 20 to 1. But to roll the weight of these doors horizontally in such a manner that the doors also swing away from the load is as easy for one man as it would be for him to roll a 1,500-lb. truck along a level track, requiring him to overcome only rolling friction.

Another feature of the Clark balanced doors is that they are locked together at the center so that there is no tendency for a gap to develop between them. This is unquestionably a marked advantage when it is understood that the length of the joint between the doors is from 8 to 9 ft. for all the newer types of ore cars. This lock operates very much like the coupling between two cars, and the doors are drawn closely together when locked.

Fig. 2 shows the balanced doors as applied to car No. 210. To open them, the operator pulls up the lever at (A), which permits the shaft and latch at (B) to rotate and release the doors, permitting them to roll to the open position shown in dotted outline. The spring on the latch between (A) and (B) returns the latch to normal position after it passes the corresponding latch on the opposite door. These latches are made so that they slide over each other to latch the door when closed or to release the latch for opening. After the load has been dumped, the operator places a wrench on the square shaft (C) and pulls down on it until the latches at (B) are engaged. He then returns the lever (A) to its normal closed position. The latches are alike, and complement each other, so that the doors may be opened and closed from either side of the car. The two doors are moved in unison by means of a connecting link (D) between the bell cranks (E) and (F) at the ends of the doors. The horizontal girders (G) on the doors prevent any tendency to gap or spring open toward the ends when latched at the center; and as the doors are fastened together directly at the line of contact, there is no gap due to lost motion in the operating parts.

The hopper slopes are 55° on all sides, including the valleys. The hopper opening is 45 sq. ft. in area. The cubic capacity for the cars in service on the Duluth & Iron Range Ry. and the Duluth, Missabe & Northern Ry. is 820 cu. ft., while for the cars for the Lake Superior & Ishpeming Ry. it is 950 cu. ft.

Car No. 210 has been opened and closed by hand by one man in 4 secs. It has dumped a load of 100,000 lbs. of ore and had the doors closed by hand by one man in 12 secs. Its average time shown in the accompanying summary of dumping tests was 1 min. 37 secs. for various kinds of ore; but at no time did the car require the attention of several men to perform the operation of dumping.

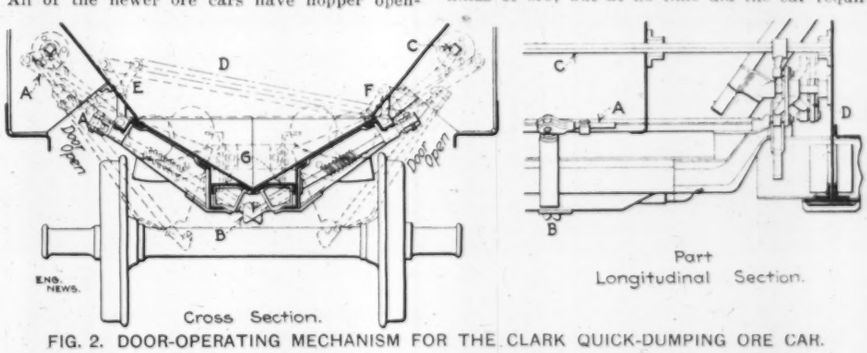


FIG. 2. DOOR-OPERATING MECHANISM FOR THE CLARK QUICK-DUMPING ORE CAR.

Referring again to the dumping tests on the Duluth, Missabe & Northern Ry., it should be noted that Summers car No. 10,384 and Rakowsky car No. 100 were operated by air exclusively. Clark car No. 210 was operated by hand on two tests, and by air on three. It was found, however, that the hand operation on this car was as quick as its operation by air. But either its air or hand performance was much quicker than for cars having some form of a swinging door. The reason for this is obvious in that the balanced door motion is such as to require no more effort in closing than in opening, in either case the work being simply to overcome rolling friciton.

SUMMARY OF TESTS OF ORE DUMPING CARS ON THE D., M. & N. RY.; 1909.

Car.	No. of tests.	Ave. men per car.	Ave. time. Per car. min.	Ave. time. Per car. sec.	Ave. time. Per man per car. min.	Ave. time. Per man per car. sec.	Failures to operate.
Summers, No. 101	12	5.00	4	21	21	45	None
Summers, No. 9,985	14	2.80	2	41	7	54	None
Summers, No. 10,384	12	2.25	1	39	3	43	None
Rakowsky, No. 100	32	1.47	2	00	2	56	1
Clark, No. 170	25	4.50	3	18	14	51	2
Clark, No. 210	5	1.00	1	37	1	37	None

*This article supplements a previous article on ore dump cars in our issue of Oct. 27, in which the Clark car was referred to but was not described.—Ed.

†Engineer, Clark Car Co., Frick Annex, Pittsburg, Pa.

AN INTERNATIONAL EXHIBITION of recent inventions in engineering and iron-working is to be held at Budapest, Hungary, from May 1 to June 30, 1911. The President of the Exhibition is Mr. Leo Lanczy, President of the Chamber of Commerce and Industry of Budapest. The Director is Mr. Armin Biro, General Secretary of the Association of Hungarian Iron Dealers. Mr. Joseph Baneth, of Budapest, is in the United States promoting the interests of the Exhibition, with headquarters at the Herald Square Hotel, New York City, until Dec. 20.

A German Sanitary District and the Imhoff Sewage-Purification Tank.

With Introduction by RUDOLPH HERING, M. Am. Soc. C. E.

Introduction.

When it became apparent a few years ago that Europe was on the eve of making some material advances in the art of sewage purification, a visit and study of the works, chiefly in England and Germany, resulted in my communicating to Engineering News a few articles on the Fundamental Principles of Sewage Purification on Land, to assist in understanding the successes and failures of some of the sewage purification works of America and Europe. Some further articles were to follow concerning the preparatory treatment of sewage prior to its final oxidation, but from lack of time their appearance has been postponed. In fact, meantime progress continued in some directions which suggested a further study last summer at close range. It was particularly desired to observe the advances made in both England and in Germany in separating the liquid and sludge and in treating the latter.

On this second trip I was accompanied by Prof. F. H. Bass, of the University of Minnesota, and by Mr. Charles Saville, then Assistant Engineer, Massachusetts State Board of Health, Boston, Mass.

It was apparent to me that the sludge question, which had been the bête noir for 30 years, was nearing a satisfactory solution. The Imhoff tank, built at a number of places in Germany and based upon what had appeared to me a rational principle, was completely fulfilling its promises of two years before, by transforming the compacted suspended matter or sludge into inoffensive humus material. The reason for this inoffensiveness was a complete digestion under favorable conditions, of all of the material that usually becomes foul.

A further advantage of this tank was the fact that the process of digestion occurred under water, and was accomplished by means of bacteria developing inodorous methane and carbon monoxide gases instead of malodorous sulphureted hydrogen as was common in septic tanks. The gases escaping from the Imhoff tank, therefore, also created no nuisance whatever. No final explanation of the suppression of the sulphureted hydrogen development was offered last summer.

It had appeared to me two years ago that this digestion might be similar to that which is accomplished by specific bacteria of fermentation in the production of beer, wines, etc., and to the action of specific bacteria which are now fed to the soil for the better growth of certain plants. There was naturally developing in the secluded sludge a gradual preponderance of bacteria producing methane and carbon monoxide gases, and a corresponding suppression of those producing sulphureted hydrogen.

In an ordinary septic tank the inflowing sewage constantly supplies many different species of bacteria to the sludge, which clearly hinders an extensive development of any single and of the most favorable species, which latter condition is possible only when the sludge as in the Imhoff tank is entirely separated from the incoming fresh sewage and is subjected to a special treatment favoring special bacteria.

Further, in order to prevent the gradual reduction of bacteria in the sludge by the development of toxins, the digested sludge is frequently withdrawn in small quantities, which permits frequent internal movements and the exposure of fresh surfaces of sludge every few days to renewed bacterial activity, thus maintaining much better conditions than in the septic tank for continuous activity and for the selection of the most favorable species. This causes a constant production of methane and carbon monoxide gas bubbles, which by their tendency to rise further tend to produce the desired sludge displacements. By such interaction the generous evolution of gas within the fermenting sludge of the Imhoff tank may be further explained.

How far these explanations are correct or incorrect the future will show. The two very important facts remain, namely, that the sludge from the Imhoff tanks has no offensive odor when withdrawn after its digestion, and that the sewage, if it is fresh when reaching the tank, is fresh also when leaving it, and is free from all but the finest particles of suspended matter. It can, therefore, often be safely discharged into a river where this would have been objectionable in its original condition of raw sewage.

The accompanying article, written by Mr. Charles Saville, who resigned from the Massachusetts State Board of Health to remain in Germany as assistant to Dr. Karl Imhoff, gives a detailed description of the tank and of its operation. The perusal will be of interest to engineering readers.

It should be noted specially that no prior settling basin is used except to keep out the grit from a combined sewerage system, the velocity of the sewage in passing through the tank being not less than 8 ins. nor more than 12 ins. per second. Nothing therefore is deposited in this grit chamber that renders its contents foul. The sand is utilized for resurfacing the sludge drying beds.

It should further be noted that the effluent is free from odor except when the sewage is noticeably septic on arrival, which it is the intention to avoid wherever possible by having smooth surfaces and good grades for the sewers, and that the entire plant can be kept odorless. I saw the installation of these tanks at Schwerin in Mecklenburg, Germany, at which the sewage of the entire city is settled and treated Imhoff tanks without odor and within sight the Ducal Palace, one of the most beaut in Europe.

The rapid drying of the tank sludge is ther noticeable feature, its absence of odor Besemblance to porous garden loam, and t lear and odorless character of the drainage w is- suing from it.

The operation of the tanks requires so in- telligence if these benefits are to be secur but the cost of operation is generally quite lo

About two years ago I recommended th rec- tion of an experimental Imhoff tank in ila- delphia, Pa., and a year ago a similar in Chicago, so as to have actual tests der American conditions of sewage and climate The Philadelphia tests, which have since been om- pleted, have fully substantiated the expe nce obtained abroad. At Chicago the experi nts are still under way.

At the present time Imhoff tanks are der construction for Holmesburg, a suburb of ila- delphia, Pa., and for the sewage of the tire city of Atlanta, Ga. They have also been r om- mended for Batavia and Oswego, N. Y. and for several other cities.

Mr. Saville's paper discusses also another im- portant subject, namely, the Emscher Valley sewerage district, its organization and laws. Nowhere else can a sewerage district be found comprising so many communities, with an equally efficient and economical organization under competent engineering guidance, and equally efficient and just laws under which it can operate. It is well worth studying with reference to similar conditions in America.

Rudolph Hering.

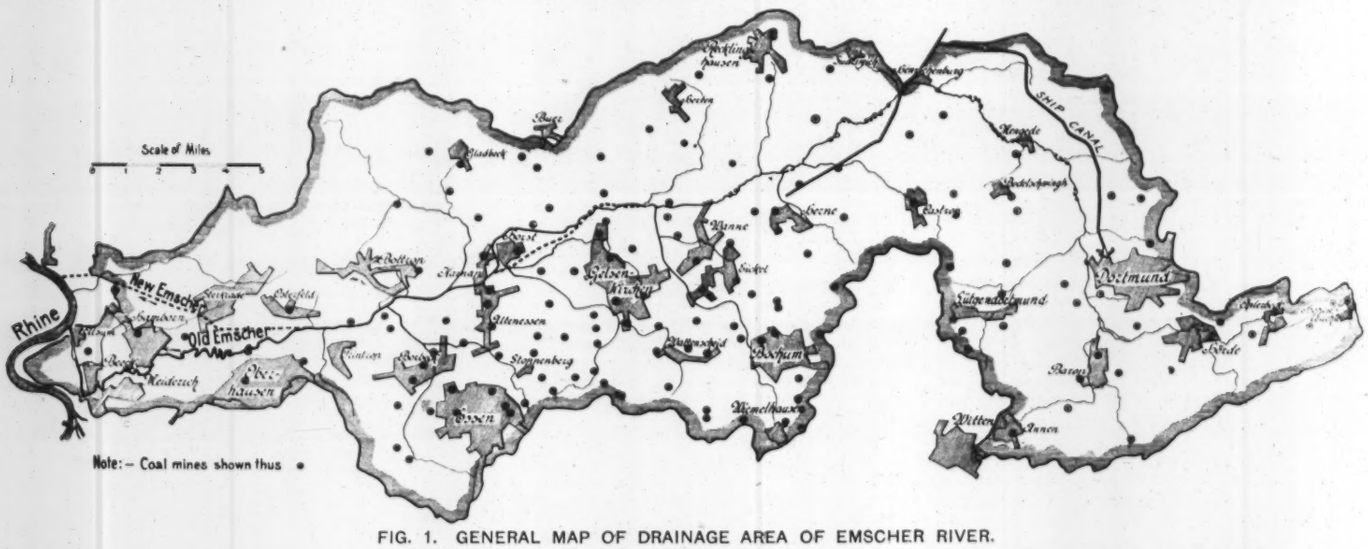


FIG. 1. GENERAL MAP OF DRAINAGE AREA OF EMSCHER RIVER.

THE EMSCHERGENOSSENSCHAFT AND THE IMHOFF TANK.

By CHARLES SAVILLE.*

In dealing with the rapidly growing problems of sewerage and sewage disposal in closely-settled districts, various methods of organization and administration have been tried in America. A new form of administration now being tried out in Germany does not as yet exist in either America or England, namely, a commission served by experienced engineers and empowered by the government to exercise complete control over sewerage throughout the drainage area of a sizable river. The experiment is proving so successful that it is likely to be duplicated in other parts of the German Empire.

The Emschergenossenschaft.

The board or commission referred to is the Emschergenossenschaft. It has its headquarters in the city of Essen, the home of the great Krupp steel and iron industry. For the past few years the board has been at work carrying out

*Assistant Engineer, Sewerage Department, Emschergenossenschaft, Essen, Germany; formerly Assistant Engineer, Massachusetts State Board of Health, Boston, Mass.

comprehensive plan for improving the unsanitary conditions in the valley of the Emscher River.

THE EMSCHER VALLEY.—The drainage area of the Emscher (see map Fig. 1) is located in the heart of the coal and iron industrial district of western Germany. It covers an area of 308 sq. mi. and has a population of about 2,000,000. Essen, the largest city in the district, now has nearly 300,000 inhabitants, an increase of more than 100% during the past ten years; ten of the other municipalities have a population of more than 50,000 each. The average density of population for the entire drainage area is approximately 6,500 per sq. mi.

Some of the coal lands are still undeveloped, but they are being opened up year by year, so that the present rapid increase in population is likely to continue, and the sanitary conditions would naturally become worse rather than better.

The main stream has its source in the vicinity of Dortmund, and flows in a general westerly direction for a distance of 68 mi. to the Rhine which it joins at a point 50 mi. below Cologne and 125 mi. above its mouth. The total fall in the course of the Emscher is nearly 400 ft.; but there are long stretches where the bed of the river has practically no slope and the velocity of flow is slight. Much of the land throughout the district is under cultivation. The soil is rather impervious, however, and wooded areas are not extensive, so there would naturally be a small flow in the streams during dry weather. Practically no ponds or storage reservoirs are to be found within the watershed. On the other hand the rainfall (approximately 30 ins. annually) is distributed uniformly throughout the year, and the normal yield of the watershed is increased by the sewage of some cities which obtain their water from other drainage areas. Water is also discharged into the river from coal mines (of which a number are located close to the limits of the district), being pumped out of the ground from depths varying from 500 to 2,500 ft.

The coal-mine drainage constitutes under present conditions a little less than *one-third* of the total flow of the stream, while the sewage from the various municipalities forms an equally large proportion of the river. The average quantity of water flowing in the Emscher at its mouth is approximately 318 cu. ft. per sec., or 66,700 gals. per sq. mi. of watershed per day. The minimum average flow during any one month is ordinarily not less than 191 cu. ft. per sec., as compared with a minimum flow in the Rhine, where it receives the discharge of the Emscher, of 30,420 cu. ft. per sec. (from 59,500 sq. mi.).

Ten years ago when the sanitary conditions in the Emscher valley began to be seriously considered, only a small part of the population was provided with adequate sewerage facilities. Only two of the cities had complete systems of sewers, one a combined system with disposal by broad irrigation outside of the drainage area, the other a storm-water system only (which, however, received much pollution from the house cesspools) with chemical precipitation treatment and ultimate discharge into a tributary of the river. In those municipalities not provided with sewers the brooks were seriously polluted by sewage and wastes of all kinds.

Also, the coal-mine drainage carried in suspension large amounts of fine coal dust, which settled out where the current was slight. At some of the mines this drainage was subjected to sedimentation before being discharged into the river, but as a rule the works were so poorly designed and operated that they were not effective in keeping the coal sludge out of the stream. Iron works and factories of all sorts contributed in similar ways to the pollution of the river.

Another important factor in the situation was the gradual sinking of the ground in many sections, from the working of the mines. Such settling of the soil along the course of the stream led to the formation of extensive shallow basins, which gradually became filled with coal sludge and other refuse, thus bringing about extremely unsanitary conditions.

The odors arising from the brooks and flooded areas were very objectionable, while much of the land was unsightly and so poorly drained that it could not be used for agricultural purposes and had become a breeding place for mosquitoes. Fortunately there is seldom continued hot weather or drought in this section of Germany so that conditions were not as bad as they might have been in the United States.

Conditions were steadily becoming worse, and with the rapid increase in population it became imperative to take steps to abate the nuisances then existing and provide proper sewerage and drainage for the entire district.

PRELIMINARY STEPS.—The Prussian Government had already issued orders for the cities and larger towns in the valley to provide proper sewerage, without stating definitely, however, what disposition was to be made of the sewage. In 1902 a number of the municipalities and industrial corporations most interested joined forces to form an association for making a thorough investigation and outlining a plan of action. During the following two years all questions relating to the subject were carefully studied by experts employed for this purpose. The report of the chief engineer, Königlicher Wasserbauinspektor Middeldorf, was presented to the association on Jan. 1, 1904. It contained, in addition to a description of the existing conditions, a comprehensive plan for the construction of sewers, purification plants and improved channels for the river and its tributaries; together with the draft of a bill to be submitted to the Prussian Government for creating a permanent board of control to have charge of the undertaking.

The work to be done, as indicated by the investigations, may be briefly outlined as follows:

1. To compel the cities and towns to provide and maintain suitable sewerage systems and proper drainage for house sewage, for liquid wastes from manufacturing establishments and for surface water; to compel the discharge of manufacturing wastes—after preliminary treatment where necessary—into the sewers instead of the streams; to abolish cesspools, not only as a means of preventing local nuisances but for the purpose of keeping the sewage as fresh as possible.

2. To design, to construct, and later on to maintain and operate main sewers common to two or more municipalities as well as all necessary disposal works for purifying the sewage. The term disposal works may here be considered to include clarification plants for the treatment of coal-mine drainage.

3. The largest and perhaps most important part of the work consisted in regulating the main stream so that the entire valley would be well drained at all times. This involved relocating the river throughout much of its course, realining, enlarging and deepening the channel of the river and many of its tributaries, and draining flooded or swampy land. From the start it was evident that it would not be feasible to provide complete biological purification for all sewage and manufacturing wastes. It thus became essential for the streams to have good grades as well as smooth and regular channels in order that there be no opportunity for the accumulation of objectionable deposits.

The total cost of the undertaking was estimated to be in the vicinity of $12,000,000, two-thirds of which would be spent for the improvement of conditions along the course of the river, the remainder being for the construction of main sewers and disposal works. This was a task requiring not only the best engineering skill for its execution but power to raise and spend money and to exercise a very complete control over conditions in a large district.

THE FINAL ORGANIZATION.—A law providing for the creation of the Emschergenossenschaft was passed by the Prussian Government in 1906, and the association thus formed proceeded at once to develop an organization competent to carry out the work already outlined. Its total membership is over 100, every Kreis (corresponding in some respects to the American county) being represented by a number of delegates, some of whom are appointed by the cities, some by the farming element and others by the mining and industrial corporations. The "Generalversammlung," or General Assembly, thus represents truly the interests of all people in the valley. It includes furthermore a number of commissioners from the State (Prussia). The representatives hold office for a term of five years, appointments being so arranged that the new members form only a small proportion of the total body.

The entire Genossenschaft does not ordinarily assemble more frequently than once a year. But the working section—"Vorstand" so-called, or Board of Directors—holds regular monthly meetings. It is a committee of ten members delegated by the General Assembly with full power to carry on the work. The state commissioners constitute a third of its membership while the other delegates include the mayors of the larger cities and directors of the mines and other important industrial organizations. A second committee elected by the Assembly is the "Berufungs-Kommission," or Board of Appeals, which must also have among its members a certain number of representatives appointed by the state.

In addition to exercising general supervision over the design, construction, and operation of the various engineering works, the Board of Directors prepares each year for consideration by the Genossenschaft a statement showing the amount of money necessary for carrying out each section of the work during the coming year. This is acted on by the Assembly, and finally approved—though sometimes in a modified form. The Board of Directors then raises the money by bond issues and makes all expenditures. The

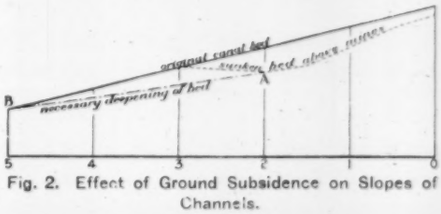


Fig. 2. Effect of Ground Subsidence on Slopes of Channels.

"budget" for the present year amounted to about $4,500,000.

A second and extremely important duty is to decide what proportion of the cost of the improvements shall be borne by the cities, what proportion by the landed interests and what by the industrial organizations. The assessments are determined each year by the Board of Directors on the basis of first, responsibility for the existing objectionable conditions in the district, and second, benefits to be derived from the improvements. These same considerations will also be kept in mind later on in determining who is to pay for future extensions or alterations of the works, made necessary, for example, by subsequent sinking of the ground. If the assessments appear unjust or the interested parties are not entirely satisfied the matter can be submitted to the Board of Appeals, whose decision is final.

If the free outlet for the water in any locality is interfered with by settling of the ground resulting from the operation of a coal mine the owners of the mine must pay for the necessary alterations in the course of the stream. And should a town persist in allowing septic sewage from cesspools to enter the common sewers it will have to pay a larger yearly assessment and its share of the expense of operating the disposal works.

In certain respects the Emschergenossenschaft possesses the same rights as a municipality. It has full control over all water courses in the district and can make such alterations, both in location and elevation of the channels of the streams, as prove desirable—irrespective of highways, railways or canals. It may, furthermore, exercise the right of eminent domain, and take and hold what land is necessary for carrying out the work. If a satisfactory agreement on price cannot be made with the owners, the question must be settled in the courts.

Work in Progress and Projected.

SEWAGE TREATMENT.—A fundamental

question in planning sewerage for the District was that of purification treatment of the sewage. Ultimate discharge into the streams being unavoidable, it was evidently necessary, in view of the small stream-flow, to give the sewage some form of treatment.

After a careful study of the several processes of sewage purification in use, and much experimental work on a practical scale, it was decided to make provision for removing from the sew-

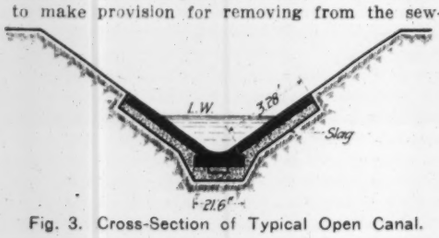


Fig. 3. Cross-Section of Typical Open Canal.

age as large a part of the suspended matter as possible, and not go to the expense of removing the dissolved organic matter except in cases where the effluent was to be discharged into small, sluggish and poorly regulated streams. This decision was to some extent based on a belief that organic matter held in solution in sewage will not putrefy so long as the sewage is exposed to the air and flows rapidly in smooth channels.

A new form of purification tank—strictly speaking a clarification tank—was developed in the course of these studies. It has proved highly successful in practice, and gives great promise of wide utility. This tank, the Imhoff tank, is described in detail farther on. It has been adopted throughout for the Emscher District, and by some 50 other communities in different parts of Germany.

MINE-WATER TREATMENT.—Although one duty of the Emschergenossenschaft is to provide means for removing the sludge from coal-mine drainage, the execution of this work has been left to the mine owners, for the reason that they are interested in reclaiming and using the coal dust, which is valuable. If the work is not carried out properly, however, the Genossenschaft can assume full control and can assess upon the mine owners the cost of building and operating suitable clarification plants.

OPEN SEWER MAINS.—Because of the occasional gradual sinking of the ground which takes place in many parts of the district it was evident that both closed sewers and open canals would be insecure and would have to be especially protected. Furthermore, the settling of the land surface being unequal, the grades of the sewers were likely to be subject to frequent disturbance. The sketch Fig 2 illustrates such conditions. In the section of the canal between sections 2 and 3 the drainage has been so interfered with that rebuilding is necessary. The bed of the canal at such points of settling cannot usually be raised to its original position, as some of the lateral tributaries will have settled in a similar manner. The only thing left to do is to lower the invert below the sunken portion, as shown in the sketch at A-B, thus restoring the outlet for the water, though with less slope. If it is desired to permanently maintain good drainage in such a mining district, the sewer mains as well as the stream beds must be made capable of deepening. This requirement is better met by open channels than by closed sewers. Open channels are cheaper to build, moreover.

The general type of canal finally adopted for the main sewers leading to the purification plants as well as for the smaller streams receiving the discharge from these works is shown in cross-section in Fig. 3.* The invert and side slopes are of smooth concrete blocks, which tend to prevent the growth of vegetable organisms on the sides of the channels. The grades are sufficient to give a rapid current, the minimum allowable mean average velocity of the water being figured at 2.3 ft. per sec.

Good grades and smooth open channels which allow of the purifying action of sunlight and air have been found effective in keeping sewage fresh, and the character of the clarified sewage gets better and better the further it goes. In some instances the sewage has a septic odor at the point where it enters the main sewer (due to the presence of cesspool cleanings) but this odor is much less noticeable when the sewage reaches the disposal works, perhaps a mile away.

Open sewers and canals must be properly fenced on both sides, and sometimes they prove rather expensive on account of the amount of land required. There must also be an inspector to care for each section of the system and remove obstructions.

A typical open canal, replacing a small watercourse, is shown in the accompanying view, Fig. 4. Comparison with Fig. 5, the same locality prior to improvement, demonstrates that the improvement in conditions effected by such regulation is well worth while. Fig. 6 gives another example of the open sewers and improved watercourses constructed in the District.

At various points along the line of the main river as well as on the principal tributaries sudden changes in grade, resulting in a drop of 3 to 10 ft., are being provided so that it will be possible to lower the beds of the streams at any point in the district whenever rendered necessary by subsidence.

After four years of active construction work there has been a material betterment of conditions all over the valley. Sewerage and suitable drainage facilities have been provided in most of the cities and towns, though as a result of the rapid growth in population there is much of this work still to be done, while in some places it has not yet been possible to abolish all the cesspools or prevent their contents being occasionally discharged into the sewers. At the end of another six months the disposal works in operation will be treating the sewage of 30% of the total population in the district.

The construction of main sewers and improved channels for the streams has already done much towards reclaiming for building pur[illegible] or agriculture large tracts of land formerl[illegible]nder water or so wet during much of the ti[illegible]hat they were useless, unsightly and un[illegible]thy. Finally, the work of straightenin[illegible] and [illegible]rov-ing the course of the main river is neari[illegible]om-pletion, which will tend to better at once [illegible] of the existing objectionable conditions in th[illegible]wer part of the valley.

All important parts of the work are li[illegible]to be in operation before 1915.

It is not possible at the present time [illegible]pre-dict with certainty just what the sanitar[illegible]con-dition of the river will be after all wor[illegible]pro-vided for in the general plan are in op[illegible]ion. The water now flowing in the stream [illegible]ow most of the principal sources of pollution [illegible]of-fensive in appearance and has an objecti[illegible]ible odor; but there is still much untreated s[illegible]age and mine drainage entering the river or its [illegible]bu-taries, nor has the main channel yet bee[illegible]n-tirely cleared of foul deposits.

The question will naturally be raised [illegible] to whether the removal of suspended solids is [illegible]ing to prove sufficient treatment for the sewage, [illegible]on-sidering local conditions and the method of [illegible]inal disposal. In any case the results will be wa[illegible]hed with interest, and especially at this time when the pros and cons of "disposal by dilution" are being discussed. After complete abolition of the cesspools has made it possible to start with fresh sewage, and efficient clarification plants have been provided for all sewage, manufacturing wastes and mine drainage, it is felt that the smooth open channels and rapid velocities will prevent odors or deposits in the streams and lead to entirely satisfactory conditions throughout the drainage area.

The most instructive thing about this Sanitary District will perhaps be found in the powers and organization of its board of control, as already described. The Genossenschaft through its [illegible]orps of engineers, numbering more than 150 me[illegible] not only designs the main sewers, the disposal works and the canals for all parts of the district and carefully supervises their construction; but also,

A Lined Canal.

The Same Stream Before Regulation.

FIGS. 4-5. IMPROVEMENT OF MINOR STREAMS IN EMSCHER SANITARY DISTRICT.

Fig. 6. Another Regulated Stream.

*Taken from article in "Wasser und Abwasser" (Band I, 1909) by Dr. K. Imhoff.

take charge of their maintenance and operation. The working of the various disposal plants is watched by competent engineers and chemists. The degree of purification effected as well as the condition of the water in the streams is also determined by regular analyses made in laboratories maintained especially for this purpose, and a well equipped experiment station is constantly in operation. With a permanent organization of this sort it has been, and will continue to be, possible to accomplish much of benefit to the people in the district drained by the Emscher.

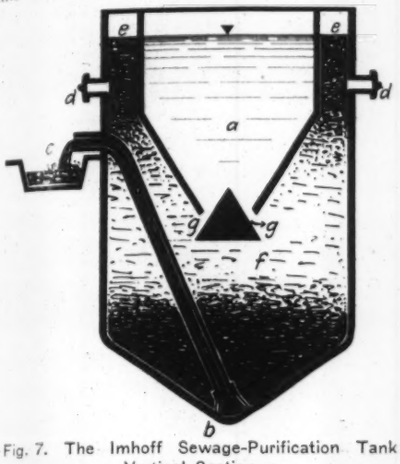


Fig. 7. The Imhoff Sewage-Purification Tank; Vertical Section.

The Imhoff Sewage-Treating Tank.

After reaching the decision to attempt nothing further in treatment of the sewage than removal of suspended matter, i. e., clarification, it became necessary to develop apparatus and procedure for the purpose. The work of developing the clarification plant best suited to local conditions was carried out by Dr. Karl Imhoff, now chief of the Sewerage Department (Abwasserabteilung) of the Genossenschaft.

Examination of many sewage-disposal works in Germany and England had shown clearly that a satisfactory removal of suspended solids was not being obtained with most sedimentation basins and septic tanks, one of the reasons being that gases which rise from the deposits on the bottom bring about a serious disturbance of the sludge and cause some of the finer sludge particles to pass out with the effluent. Furthermore, it was evident that most sewages tend to become septic during passage through the tanks (even where the settling time was comparatively short) in consequence of contact with the deposited sludge and the gases of decomposition. That this is undesirable, irrespective of whether the sewage is to receive subsequent biological purification or is to be discharged directly into a stream, is now generally admitted. The operating results at many works had also shown that the quantity of sludge which becomes liquefied through septic action is much less than originally supposed; but that sewage sludge *when once thoroughly rotted away* is unobjectionable in character and is easily handled.

At some places in Germany screens had been found effective in removing a considerable part of the larger suspended solids in sewage. But they were not considered to be applicable to conditions in the Emscher district, on account of cost for both construction and operation, and because the suspended matter in the sewage was likely to be partly decomposed (as the result of the custom of emptying cesspools into the sewers) and consequently difficult to dispose of.

THE PROBLEM.—The problem thus presented was (1) to design a tank in which sewage might have a sufficient time for settling to effect the removal of all suspended matters which could be economically separated from the water by sedimentation; (2) to provide a means of automatically removing the deposited solids from the settling chamber so that the disturbing action of the gas formed during decomposition of the sludge could not cause part of the deposits to pass out with the effluent; (3) to ensure that the sewage in its passage through the tank should not come in contact with either the decomposing sludge or the gas, in order that it might remain unchanged in character so far as the organic matter in solution is concerned; and finally, (4) to make arrangements for allowing the sludge to become thoroughly septicized, as it is only after complete decomposition of the organic matter that it becomes unobjectionable and easily handled. It is worth noting here that the question of final disposition of the sludge was given as much consideration as the clarification of the water.

THE SOLUTION OF THE PROBLEM.—A cross-section through one of the so-called Emscher or Imhoff tanks is shown in Fig. 7. The sewage passes through the settling chamber in a direction perpendicular to the plane of the drawing. The suspended solids sink to the bottom, slide down the sloping bottom surfaces of the chamber and pass through the slots *g* into the sludge well *f* beneath. All interior surfaces of the sedimentation chamber are made as smooth as possible, with a view to preventing accumulations of sludge. The settling action is thus fully as good as in other settling basins, and is subject to less disturbance because the deposited sludge is separated quickly and completely from the sewage. Gases rising from the decomposing organic matter escape into the air through openings shown at *e*. The overlap to the bottom slopes of the sedimentation chamber makes it impossible for gas to pass up through the sewage, and, as the sludge well has no outlet, sewage does not enter it from above. The sludge, after thorough septicization, gradually works its way down to the bottom of the well and is removed a little at a time through the pipe *b-c*.

The relative volumes of the sedimentation chamber and the sludge-well may be varied to suit the character of the sewage. Suitable scum boards are provided in the sedimentation chamber to prevent grease and light floating matters going out with the effluent.

Previous to passage through the tank large objects such as sticks or tin cans are removed from the sewage by coarse bar screens, and in most cases grit chambers (with a settling time of only a few minutes) are provided for taking out sand and other heavy mineral matters carried in suspension.

A clarification plant of this type was first operated in 1906. At the present time seven such plants are in use, serving a total population of 250,000. Similar works for 10 more municipalities are being built, and it is expected that 30 others will eventually be constructed in various parts of the district.

OPERATION.—The period of sedimentation at the different plants ranges from one to two hours, which is sufficient to separate from the sewage 95% or more of all suspended matters capable of removal by sedimentation.* This bears out the results of other investigations recently made in Germany, which show that the economical settling-time for ordinary sewage is less than two hours.

It is considered undesirable to remove any part of the suspended organic matter in the sewage, previous to its treatment in the main tank, by means of either screens or sedimentation in a grit chamber. Deposits removed from the grit chambers consist only of clean sand. In small installations where street drainage is excluded from the sewers the grit chambers are dispensed with altogether.

The time allowed for thorough septicization of the sludge varies with the character of the sewage, being usually as much as four or five months. As the tanks are 25 ft. deep or more, this process of rotting out the decomposable organic matter takes place under very favorable conditions.

ABSENCE OF ODOR.—The large quantities of gas rising from the sludge are found to be inodorous. Numerous analyses have shown the presence of approximately 75% marsh gas and 25% carbon monoxide, but practically no sulphureted hydrogen. No satisfactory explanation has yet been offered of the almost entire absence of the latter. As already pointed out, there is no flow through the sludge well, and sewage containing fresh organic matter in solution does not enter it; such conditions may be more favorable to the development of bacteria that produce inodorous marsh gas than to the better known variety which give us so much ill-smelling sulphureted hydrogen. The small amounts of scum which collect on the surface of the water in the sludge wells do not have an objectionable odor and can be easily removed (through outlets shown at *d*, Fig. 7) if their presence interferes with the escape of the gases.

FIG. 8. SEWAGE PURIFICATION PLANT AT RECKLINGHAUSEN (pop. 26,000).

The effluent from the sedimentation chamber is not only well clarified, but is free from odor except in cases where the sewage is noticeably septic on arrival at the plant. Even in such instances the sewage does not deteriorate in character during its passage through the tanks, and there is never a noticeable odor in the vicinity of the works.

SLUDGE DISPOSAL.—The sludge when removed from the tanks contains only 75% to 80% water, but flows readily in concrete channels to

*See article by Dr. Imhoff in "Gesundheits-Ingenieur," Aug. 20, 1910.

the sludge-drying beds. Its ease of flow through pipes or open channels can perhaps be explained by the complete rotting out of the putrescible organic matter and the fineness of the remaining particles. In the drying-beds it dries rapidly, becoming firm and "spadable" in three or four days. The sludge has absolutely no objectionable odor; it is used for filling low areas around the disposal works. Its appearance, in fact, is that of porous garden loam. It is dark gray in color and develops luxuriant vegetation after a few months. The sludge dries so rapidly—partly as a result of the gas it contains when first removed from the tank—that very small drying-beds are requireed.[1]. At Bochum, for example, where the sewage from a population of 145,000 is treated, these sludge-drying beds cover an area of only half an acre. In some places the sludge (after the first six months have elapsed) is removed in small amounts every week or so, while in other instances it is taken out of the tanks only once or twice a year. The water which drains out of the sludge while on the drying-beds is clear and odorless.

The method of sludge disposal thus perfected in the Emscher district is the outcome of an attempt to transform all objectionable organic suspended matter in sewage into a stable firm condition such as ordinary soil. To make this possible on a small area the sludge must be thoroughly septicized in deep wells—as described—so that it will dry quickly on the beds. Being then comparatively free from moisture it can be deposited on the land in thick layers, which minimizes the effect of rain and furnishes pressure to compact the material.

All of the disposal plants now in operation are located close to thickly populated districts; but no complaints of any sort are made. The tanks, though uncovered, are almost entirely below the ground level, and the areas controlled by the Genossenschaft are attractively laid out with neat paths, trees and flower beds. Fig. 8 shows the tanks and sludge-drying beds at Recklinghausen, one of the first towns for which a clarification plant was provided.

The cost of operation of these plants is extremely low. It averages about $2.25 per million gallons (including fixed charges[2]) or 0.07 cts. per capita per year. The work consists largely of cleaning the screens and grit-chambers at regular intervals and transferring the dried sludge from the beds to the point of final deposit.[3]

The New Commerce Court for Trying Railway and Transportation Suits.*

By PAUL SYNNESTVEDT.†

The power in the regulation of rates and in the determination of the rules and regulations concerning safety appliances which is vested in the Interstate Commerce Commission is now only beginning to be appreciated. That commission is composed of men of high standing, great ability, and practical knowledge, and yet it must be considerably removed from a judicial character or temperament. Therefore, there is recognized in the law, and there has been followed for some time, a practice of appealing from decisions or rulings of the Interstate Commerce Commission to the courts. These proceedings have been increasing in number, and it was thought best to make provision for some special tribunal to hear all of these cases.

The creation of a "Commerce Court" by an act approved by Congress on June 18, 1910, and which became effective 60 days thereafter, must excite among railway people some interest in the form or organization of such court as well as the underlying reasons for its creation.

In this legislation for the creation of a special "Commerce Court," as well as in the law recently enacted creating the "Customs Court" and in the law now pending in Congress for creation of a special "Patent Court" there is unmistakable evidence of a tendency to divide court practice into various headings under special classes arranged according to subject matter. This tendency is in marked contrast with our practice in times past. Formerly, it has been thought best to adhere to general provisions giving cognizance of various classes of suits all to the same judge or set of judges. Thereby it was apparently sought to avoid too great a degree of specialization, which by many is thought to be narrowing in its effect.

It has been an almost universal practice among countries of a commercial character to make some provision for special trial of causes of action arising out of commerce. As commerce in those days was carried on mainly by means of water transportation the courts having jurisdiction of such commercial affairs were known as admiralty or maritime courts. A court having jurisdiction of railway transportation matters is a novel thing, growing out of modern conditions, but there is certainly a strong analogy to be found in these admiralty or maritime courts. As the measure finally passed, it provided "that a court of the United States is hereby created which shall be known as the Commerce Court and shall have the jurisdiction now possessed by the circuit courts of the United States, and the judges thereof over all cases of the following kinds." The cases included may be summarized as follows:

(1) All cases for the enforcement (with sundry exceptions) of any order of the Interstate Commerce Commission other than for the payment of money. In other words, any case arising out of an effort to enforce an order of the Interstate Commerce Commission, with regard, for example, to safety appliances, would be brought in this court.

(2) Cases brought to enjoin, set aside, annul or suspend in whole or in part any order of the Interstate Commerce Commission.

(3) Such cases as by the previous Commerce Act of 1903 are authorized to be maintained in a circuit court of the United States; and (4) all such mandamus proceedings as under the provisions of the Act "to regulate commerce," passed in 1887, are authorized to be maintained in a circuit court of the United States.

The fundamental purpose of the law as it was finally passed is only to constitute and create a special judicial tribunal to hear cases arising under the interstate commerce laws (particularly acts or decisions of the Interstate Commerce Commission), instead of allowing such causes to be heard, as heretofore, by any federal circuit court anywhere in the United States.

The fundamental reason urged for the existence of such special court is based upon the proposition that the judges will be more or less expert in the particular class of work they are called upon to do. By virtue of this greater familiarity of the subject matter, they can be expected not only to act with greater expedition but also to reach a more just conclusion and to establish by way of authority a more uniform line of decisions.

It is evident that the knowledge a court would acquire through the hearing of proceedings touching an inquiry as to a requirement for electric headlights, for instance, would be of material assistance to the court in the understanding of other cases such as might arise in connection with rules or regulations concerning switch lights or block signals. Thus the special knowledge acquired in the review of one case of technical character becomes so much capital to be used by the court in connection with subsequent proceedings of an analogous character. This rule has practically little application where the litigation is scattered all over the country in courts of local jurisdiction and the questions may be reviewed by any one of perhaps two hundred judges.

The act applies to all persons engaged in the transportation of oil or any other commodity (except water and natural or artificial gas) by means of pipe lines, and to telegraph, telephone and cable companies (even wireless). It applies also to all "terminal facilities of every kind," used in transportation and also all "freight depots, yards, and ground used in transportation." It was further provided that the term "transportation" should include:

Cars and other vehicles and all instrumentalities and facilities of shipment or carriage irrespective of ownership or of any contract for the use thereof, and all services in connection with the receipt, delivery, elevation and transfer in transit, ventilation, refrigeration or icing, storage and handling of property transported.

[1] See article by Dr. Imhoff in "Technisches Gemeindeblatt," Oct. 5, 1910.

[2] The estimated cost of the disposal works for 2,000,000 people is approximately $1,200,000.

[3] The caretaker receives about $360 a year while ordinary laborers are paid at the rate of 11 cts. per hr.

* Abstract of a paper in the "Proceedings" of the Western Railway Club (Chicago) for October, 1910.

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Notes from Engineering Schools.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.—The total registration of the present academic year is announced to be 1506, which has been exceeded but three times (in 1902-3, 1903-4 and 1904-5, when the total was reported to be 1,608, 1,528 and 1,561 respectively) and then immediately preceding the increase of tuition from $200 to $250 and the raising of entrance requirements. Of this total number of students, 14% are graduates of other colleges and 27% have attended other colleges before entering here. There are 93 foreigners at this institution, representing 34 countries. The largest group in this foreign contingent is formed by 27 Chinese students sent by the Chinese government.

OHIO STATE UNIVERSITY.—The Department of Civil Engineering has published a Commemorative Bulletin prepared by Prof. C. E. [illegible]man, outlining the history of the University [illegible] of its College of Engineering and giving [illegible]phical sketches of the founders and the [illegible]sent engineering faculty. The bulletin descr[illegible] the practical summer work done about C[illegible] and in the Yellowstone National Park. T[illegible] har-acter of student scholarship, the grow[illegible] and prospects of the University have been d[illegible]ssed also. In connection with the first topi[illegible] Prof. Sherman pleasantly recalls the Engineering News thesis contests of 1892-95 in each of wh[illegible] the students of Ohio State University won so[illegible]prize and finally stood first in an average of the [illegible]sults of the series. A catalog of the alumni of t[illegible] Civil Engineering Department is appended.

CASE SCHOOL OF APPLIED SCIE[illegible]E.—The following self-explanatory rules go[illegible]ning what are termed "industrial fellowships" have been published.

(1) Upon the application of any person or [illegible]ons, the Trustees may, upon the recommendation of th[illegible]resident, establish an industrial fellowship. The pe[illegible] or persons for whom the fellowship is establish[illegible] and hereafter called the donor, shall pay to Case S[illegible]l of Applied Science such sum as is mutually agre[illegible] upon as the amount necessary to maintain the fellow[illegible]p for one year and the donor shall have the option of c[illegible]ntinuing the fellowship for a longer period if sati[illegible]factory terms can be arranged.

(2) The Fellow shall be recommended by th[illegible] President and the donor of the fellowship before b[illegible]ng appointed by the Board.

(3) The donor of the fellowship shall state in [illegible]riting what object he desires to accomplish through th[illegible] fellowship, and the Fellow shall give his entire time to the work of the fellowship and allied subjects; all of which work shall be done under the advice and direction of the donor and of some member of the faculty. The Fellow shall agree to remain during the year in which the fellowship was established and for a longer period if deemed desirable by the School and the donor.

(4) The greater part of the money paid by the donor for the support of the fellowship shall be paid to the Fellow as salary, the balance being used for purchasing special apparatus necessary for carrying on the work. The School agrees to give the use of its laboratories and such apparatus as can be spared—also the advice of the members of its faculty—without charge, but apparatus injured or destroyed in any investigation shall be replaced out of the fellowship fund given for that investigation provided any balance remains after paying the salary of the Fellow.

(5) Any and all discoveries made by the Fellow shall become the property of the donor and the Fellow shall take out at the expense of the donor any patents which the latter may deem necessary. The donor shall, however, pay to the School 10% of the net profits arising from such patents during their life, or this may be commuted at the desire either of the donor or the School through arbitration if necessary. The School will pay to the Fellow such a part of the 10% of the net profits given to it as may be mutually agreed upon.

(6) At or before the expiration of the fellowship the services of the Fellow may be secured by the donor for a period of years on condition that satisfactory terms can be arranged.

(7) The donor shall agree that any results reached which are of scientific interest and which are not necessary to be preserved as trade secrets may be published by the Fellow or by the School.

(8) The School also agrees that all work done by the Fellow shall count toward a doctor's degree if the Fellow so wishes.

A DISASTROUS FACTORY FIRE, Nov. 26, destroyed the four-story brick building on High St., near Orange St., Newark, N. J. Two or three hundred women were employed in the building, and of these 24 were killed and 40 others seriously injured. The fire started on the third floor, which was occupied by the Anchor Lamp Co. and the Aetna Electric Co. Many of the victims were on the fourth floor, where about 100 women and girls were employed in the factory of the Wolf Muslin Undergarment Co. The second floor was occupied by the Newark Paper Box Co., and on the ground floor were the factory of the Drake-Morrison Paper Box Co. and John Bievney's machine-shop. The fire is ascribed to an explosion of gasoline which occurred while one of the Anchor Lamp Co.'s lamps was being filled.

The building was built about 50 years ago, and is described in the press reports as being thoroughly saturated with oil. The flames spread very rapidly and seem to have cut off escape down the stairway from the fourth to the third floor before the employees on the fourth floor were aware of the danger. Although the building had a frontage of 150 ft., there were only two fire-escapes, one in front and one in the rear. A few of the women from the fourth floor descended safely by

way [illegible] the one fire-escape which was not made impassable by the flames, but most of them were obliged to jump from the fourth floor windows to the street and most of the deaths came about in this way.

In spite of the fact that Engine Co. No. 4 of the Newark fire department was stationed directly across the street from the factory, no alarm was given until the flames and smoke were seen by the firemen issuing from the windows of the third floor. The firemen were obliged to direct most of their efforts toward saving the women in the building, and the fire was not checked until the building had been completely destroyed with the exception of portions of the outside brick walls. It is reported that the dangerous condition of the building had been for some time widely known, although it had recently been passed as complying with the New Jersey State laws by Deputy Factory Inspector William Schlachter. An investigation has been begun by the Essex Co. Grand Jury in an attempt to fix the responsibility for the disaster.

A RAILWAY ROUNDHOUSE BURNED Nov. 18 at Nashua, N. H., on the Worcester, Nashua & Portland division of the Boston & Maine R. R. Of the eight locomotives in the roundhouse when the fire started, only three were rescued. The removal of the others was prevented by the derailment of the third engine pulled out. The five locomotives destroyed were valued at $15,000 each.

AN EXPLOSION IN AN ASPHALT MINE near Durant, Okla., Nov. 28, killed 13 men. The explosion occurred just as the day shift was entering the mine. Nine men had already been lowered to the foot of the 200-ft. shaft and five more were in the cage when the explosion occurred. The men in the cage were blown out of the shaft. One of those below escaped death and was brought to the surface by a rescue party. The mine is the property of the Choctaw Asphalt Co., of St. Louis, Mo. The explosion is attributed to the ignition of gas by a miner's lamp.

A COAL MINE EXPLOSION in Mine No. 3 of the Providence Mining Co., at Providence, Ky., Nov. 25, entombed eleven men. The shaft is obstructed by slate and rock brought down by the explosion. The mine is a new one with a shaft 100 ft. deep.

A PREMATURE BLAST on the Atchison, Topeka & Santa Fe Ry. Nov. 23 killed four men in a rock cut east of Barstow, Cal. One of the men killed, according to press reports, was H. E. Hanion, a civil engineer of St. Paul, Minn.

THE PENNSYLVANIA R. R. NEW YORK TERMINAL was opened for traffic to and from the west on Sunday, Nov. 27. About 100 Pennsylvania trains each way per day use the station at present, in addition to the Long Island R. R. trains.

A WIRELESS TELEGRAPH MESSAGE between Key West, Florida, and Norfolk, Va., was received on Nov. 22 at the station of the Mare Island Navy Yard, Vallejo, Cal., near San Francisco. The transcontinental distance is about 3,900 miles. On the following day direct communication between Vallejo and Norfolk was secured.

THE EIGHTH INTERNATIONAL CONGRESS of Applied Chemistry has been invited to the United States by President Taft. The congress will meet in Washington, D. C., in September, 1912. The secretary is Dr. Bernhard C. Hesse, 25 Broad St., New York City.

A STEEL HIGHWAY BRIDGE AT PEORIA, ILL., crossing the Illinois River, is proposed to replace the concrete-arch structure which failed in May, 1909, through undermining of the piers. Plans for a steel girder bridge have been prepared by Mr. Ira G. Hedrick, M. Am. C. E., of Kansas City, Mo. It is proposed to retain the present bascule draw span of 125 ft., which was not injured by the failure of the adjacent arch spans, and to flank this with five deck girder spans on one side and one similar span on the other side. The total length of the seven spans would be about 877 ft. The bridge would have a 30-ft. roadway and two 5-ft. sidewalks. The estimated cost is given as $165,000. The city has voted to issue bonds for $250,000 for a new bridge, and $130,000 have been raised already by the sale of the bonds, while the balance of the old bridge fund increases the amount to $147,000. The remainder of the bonds will not be sold until the amount of additional money required is determined. The removal of the debris of the old structure to the level of 9 ft. above low water will soon be completed, and it rests with the government engineers to determine what additional amount of removal will be required for clearing the channel.

THE AMERICAN MUSEUM OF SAFETY formally opened its permanent exposition Nov. 21 at the Engineering Societies Building, 29 West 39th St., New York City. At the opening exercises, two gold medals, the first ever awarded by the museum, were presented, one to the Patent Scaffolding Co. and the other to the United States Steel Corporation. The first was awarded for excellence of a single device for the protection of workmen and the second for completeness and excellence of a system of safety appliances for the protection of employees.

The permanent exposition of safety appliances, on the sixth floor of the Engineering Societies Building, is intended to advance the movement for the elimination of unnecessary industrial accidents. The exhibits comprise actual machines, models and photographs of safeguards for workmen in connection with motors, elevators, steam boilers, explosives, railways, ships, etc. The officers of the American Museum of Safety are Philip T. Dodge, President; Charles Kirchoff, Vice-President; T. Commerford Martin, Chairman of executive committee; Frederick R. Hutton, Chairman of committee of plan and scope; Dr. N. E. Ditman, Chairman of department of sanitation.

THE RIVERS AND HARBORS ESTIMATE for the fiscal year ending June 30, 1912, as just submitted to the Secretary of War by Gen. W. H. Bixby, Chief of Engineers, U. S. Army, shows a marked decrease from those of recent years. It will be remembered that President Taft, in signing the last Rivers and Harbor Bill appropriating some $52,000,000 for the present year, stated that in future he would sign no similar bill wherein the "pork-barrel" features were so prominent, and recommended that the Chief of Engineers reduce his estimates and that Congress reduce its appropriations for river and harbor work, so that only ordered schemes be followed in future. The present estimate is for $30,095,698, of which $7,368,077 is for a continuance of present contracts. Many of the pet schemes of the waterways boomers are not included in these latest estimates. Among these are the 14-ft. channel from Chicago to the Illinois River, and the deep channel of the Missouri River from St. Louis to Kansas City. For the Mississippi River, "in order to continue improvements from the head of the passes to the mouth of the Ohio River, including the expense of the Mississippi River Commission," $3,000,000 is estimated; from the mouth of the Ohio to the Missouri, $1,000,000; from the Missouri to Minneapolis, $1,250,000; and for the construction of the lock and dam between St. Paul and Minneapolis, $250,000.

A VERY FAST SHORT RUN TRAIN SERVICE has been inaugurated by the Central Railroad of New Jersey between New York and Philadelphia. Twelve trains daily in each direction are now scheduled to make this trip in 110 mins. The distance from the Jersey City terminal, which has to be reached from New York by ferry, to the Reading terminal in Philadelphia is 90.2 miles and the schedule is 100 mins. As some miles of the trip are through cities where reduced speed is required, the average running time of the train in the open is well above 60 miles per hour. It is reported that the first train to follow the new schedule, the one leaving Jersey City at 9.10 a. m., Sunday, Nov. 27, made the 90.2 miles in 97 mins., and that it attained a speed of 92¾ miles per hour for a distance of three miles. For 26 miles an average speed of 64¼ miles per hour was maintained.

Personals.

Mr. John I. Rogers, formerly of the Midvale Steel Co., of Philadelphia, Pa., has opened an office as a consulting engineer at 165 Broadway, New York City.

Mr. A. Dinan, formerly Division Master Mechanic of the Atchison, Topeka & Santa Fe Ry. at Ft. Madison, Iowa, has been made Mechanical Superintendent of the same railway at Amarillo, Tex.

Mr. C. J. Stewart, recently Master Mechanic of the Central New England R. R. at Hartford, Conn., has been appointed Master Mechanic of the New York, New Haven & Hartford R. R. at Waterbury, Conn.

Mr. J. E. McMahon, formerly Train Master of the Atchison, Topeka & Santa Fe Ry., at Las Vegas, N. Mex., has been promoted to Superintendent of the new Pecos Division with headquarters at Clovis, N. Mex.

Mr. W. T. Noonan, formerly Vice-President and General Manager of the Buffalo, Rochester & Pittsburg R. R., has been elected President, succeeding Mr. Adrian Iselin, who has been elected a Vice-President.

Mr. Curtis Dougherty, Engineer of Maintenance-of-Way of the Alabama Great Southern R. R. (Queen & Crescent Route) has been made Chief Engineer, and the office of Engineer of Maintenance-of-Way has been abolished.

Mr. John Flynn, Jr., M. Am. Soc. C. E., formerly City Engineer of Troy, N. Y., has been appointed Special Deputy City Engineer in charge of preparation of plans and the construction of the storage reservoir on the Quacken Kill.

Mr. D. Elliott, formerly Assistant Superintendent of the Eastern Ry. of New Mexico, has been appointed Superintendent of the Plains Division of the Atchison, Topeka & Santa Fe Ry. He will continue to keep his headquarters at Amarillo, Tex.

Mr. James C. Hallock, M. Am. Soc. C. E., has been made Deputy Chief Engineer of the Board of Public Works of Newark, N. J. Mr. Hallock is a graduate of Rensselaer Polytechnic Institute, class of 1891, and has been Assistant to Chief Engineer Sherrerd of the Board of Public Works for the past 18 months.

Mr. Virgil G. Bogue, M. Am. Soc. C. E., formerly Vice-President and Chief Engineer of the Western Pacific Ry., was the guest of the Pacific Northwest Society of Engineers at a banquet in his honor held at the Washington Hotel in Seattle on Nov. 19. Mr. Archibald O. Powell, M. Am. Soc. C. E., of Seattle, acted as toastmaster. About 75 engineers and their guests were present.

Mr. Bogue resigned his position with the Western Pacific Ry. last January and has resumed his practice as a consulting engineer in New York City, after spending four years in charge of the construction of this railway. Mr. Bogue graduated from Rensselaer Polytechnic Institute in 1868. In 1887 he became Chief Engineer of the Union Pacific Ry. After holding this position for five years he opened an office in New York as a consulting engineer, dealing especially with railway problems.

Mr. John C. Olmstead, a landscape architect of Boston, Mass., has been selected by the city of San Diego, Cal., to supervise the work on the grounds and buildings for a Panama-California Exposition, which will be held in celebration of the opening of the Panama Canal. The site of the fair grounds is Balboa Park. Many of the buildings and other features will be permanent. The sum of $1,000,000 has been raised by a city bond issue, and $1,000,000 has been subscribed by citizens and others interested in the fair.

Obituary.

Robert Monroe, President of R. Monroe & Sons Mfg. Corporation, of Pittsburg, Pa., died at his home on Nov. 24, at the age of 76. He was one of the pioneer boiler and steel manufacturers of Pittsburg and a veteran of the Civil War.

Charles P. B. Jefferys, an old-time engineer, died in New York City on Nov. 25, at the age of 79 years. He was born at Liège, Belgium, and was educated at the University of Liège. He came to this country in 1848 and was an engineer on construction of the Pennsylvania R. R. during its early days. He had not practiced engineering for nearly 30 years.

Danton H. Nichols, formerly prominent in railway operation, died on Nov. 27 at Monroe, La. He was born at Lima, Ohio, on Aug. 14, 1849, and in 1866 he was clerk and office boy with the St. Louis & San Francisco Ry. Thereafter he was successively, brakeman, baggageman, conductor, clerk in the general freight office, car accountant, general baggage agent and later traveling auditor of the same road. In 1875 he became Superintendent of the Atlantic & Pacific Division of the same railway, later Superintendent of Transportation, and in 1890 General Superintendent. The same year he went to New England as Division Superintendent of the New York & New England R. R. and soon became General Superintendent of this road. In 1898 he became Superintendent of the Pecos Valley Ry. of Texas, and in 1903 Division Superintendent of the St. Louis & Gulf Ry. and the St. Louis, Memphis & Southeastern Ry. He had made his home at Springfield, Mo.

Octave Chanute, Past President of the American Society of Civil Engineers, died at his home in Chicago on Nov. 23. He was born in France in 1832, and was brought to this country in 1838. His engineering career commenced in 1849, when he was engaged on the Hudson River Ry. under the late John B. Jervis, then Chief Engineer. Of late years he had taken active interest in the development of aviation, and the present success of flying machines of the aeroplane type is due largely to the work of Mr. Chanute. When in Europe last summer he contracted pneumonia, and had a very serious illness. He returned to this country in October, but was unable to regain strength and died practically of extreme weakness and exhaustion. A very complete biography (which was read and approved by him a few weeks ago) was published in our issue of Nov. 17.

Funeral services were held at the residence on Nov 25, at which a number of prominent engineers and associates of Mr. Chanute were present. The burial was at Peoria, Ill., on Nov. 26.

Engineering Societies.

COMING MEETINGS.

NEW JERSEY SANITARY ASSOCIATION.
Dec. 2-3. Annual meeting at Lakewood, N. J. Secy., J. A. Exton, 75 Beech St., Arlington, N. J.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.
Dec. 5-6. Annual meeting at New York City. Secy., W. H. Ross, 154 Nassau St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
Dec. 6-9. Annual meeting at New York City. Secy., C. W. Rice, 29 West 39th St., New York City.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.

Dec. 7-9. Annual meeting at New York City. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.
Dec. 12-14. Annual convention at New York City. Secy., Percy H. Wilson, Land Title Bldg., Philadelphia, Pa.

NATIONAL ASSOCIATION OF CEMENT USERS.
Dec. 12-17. Annual convention at New York City. President, Richard L. Humphrey, Harrison Bldg., Philadelphia.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 27. Annual meeting at St. Paul, Minn. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS.
Dec. 27-28. Annual meeting at Lafayette, Ind. Secy., E. W. Hamilton, Iowa State College, Ames, Iowa.

CANADIAN SOCIETY OF CIVIL ENGINEERS.
Jan. 2-6. Annual meeting at Winnipeg, Man. Secy., C. H. McLeod, 413 West Dorchester St., Montreal, Que.

INDIANA ENGINEERING SOCIETY.
Jan. 12-14. Annual meeting at Indianapolis, Ind. Secy., Charles Brossmann, Indianapolis, Ind.

MONTANA SOCIETY OF ENGINEERS.
Jan. 12-14. Annual meeting at Helena, Mont. Secy., Clinton H. Moore, Leyson Block, Butte, Mont.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.
Jan. 17. Annual meeting at Pittsburg, Pa. Secy., Elmer K. Hiles, 803 Fulton Bldg., Pittsburg, Pa.

AMERICAN INSTITUTE OF ARCHITECTS.
Jan. 17-19. Annual convention at San Francisco, Cal. Secy., Glenn Brown, the Octagon, Washington, D. C.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 18-19. Annual meeting at New York City. Secy., Charles Warren Hunt, 220 West 57th St., New York City.

ILLUMINATING ENGINEERING SOCIETY.
Jan. 20. Annual meeting at New York City. Secy., P. S. Millar, 29 West 39th St., New York City.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.
Jan. 24-26. Annual meeting at New York City. Secy., W. M. Mackay, P. O. Box 1818, New York City.

OHIO ENGINEERING SOCIETY.
Jan. 24-26. Annual meeting at Columbus, Ohio. Secy., C. J. Knisely, New Philadelphia, Ohio.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 25-27. Annual meeting at East St. Louis, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago, Ill.

NATIONAL BRICK MANUFACTURERS' ASSOCIATION.
Feb. 6-11. Annual convention at Louisville, Ky. Secy., T. A. Randall, Indianapolis, Ind.

CANADIAN CEMENT AND CONCRETE ASSOCIATION.—The annual convention and exhibition will be held at Toronto, Ont., Jan. 16-20. It is expected that many of the exhibits at the cement show in New York City will be shown again at Toronto on their way to the Chicago exhibition in February. The secretary is Mr. R. E. W. Hagarty, 662 Euclid Ave., Toronto, Ont.

AMERICAN ROAD BUILDERS' ASSOCIATION.—The program for the seventh annual convention at Indianapolis, Ind., Dec. 6-9 has been nearly completed. Among those who have consented to either make addresses or prepare papers on subjects with which they are especially familiar are the following: N. J. Bachelder, Master of the National Grange, "The National Grange and Good Roads"; F. J. Robinson, Deputy Minister of Public Works, Province of Saskatchewan, Canada, "Pioneer Road Making in Saskatchewan, Canada"; Samuel Hill, President Washington State Good Roads Association, "Convict Labor in Road Building"; S. Percy Hooker, Chairman New York State Highway Commission, subject to be announced; Major W. W. Crosby, Chief Engineer, Maryland State Roads Commission, "A Division of Road Interests for Better Results"; James H. MacDonald, State Highway Commissioner of Connecticut, subject to be announced; Harold Parker, Chairman, Massachusetts State Highway Commission, subject to be announced; Col. Frederick Gilkyson, Commissioner of Public Roads of New Jersey, subject to be announced; A. B. Lea, Director Public Service of Cleveland, Ohio, "Relation of the City to Its Adjacent Country Highways"; A. N. Johnson State Highway Engineer of Illinois, "Some Features of Road and Bridge Construction"; E. J. Watson, Commissioner of Agriculture of South Carolina, subject to be announced; James C. Wonders, State Highway Commissioner of Ohio, "Present Highway Laws of Ohio and the Proposed New Law"; C. D. Miller, Assistant Territorial Engineer of New Mexico, subject to be announced; Jos. W. Hunter, State Highway Commissioner of Pennsylvania, "Application of the Highway Law of Pennsylvania"; Townsend A. Ely, State Highway Commissioner of Michigan, "Progress of Road Building in Michigan"; Logan Waller Page, Director U. S. Office of Public Roads, "State Highway Legislation"; Geo. W. Cooley, State Engineer of Minnesota, subject to be announced; Charles P. Light, Commissioner of Roads of West Virginia; "Earth Roads"; Jos. Hyde Pratt State Geologist of North Carolina, "The Best Method of Supervision and Control of Road Construction in a State"; Samuel H. Lea, State Engineer of South Dakota, "Road Building in South Dakota"; T. R. Atkinson, State Engineer of North Dakota, "Road Building in North Dakota"; Paul D. Sargent, State Highway Commissioner of Maine, subject to be announced; W. O. Hotchkiss, Chief of Highway Division, Geological Survey of Wisconsin, subject to be announced; P. St. J. Wilson, State Highway Commissioner of Virginia, subject to be announced; W. S. Gearhart, State Highway Engineer of Kansas, "Bridge and Culvert Construction."

SANITARY OFFICERS OF THE STATE OF NEW YORK.—The tenth annual conference of the Sanitary Officers of the State of New York was held at Buffalo, Nov. 16 to 18. A large number and considerable variety of papers were presented. Sectional meetings were held part of the time in order to suit the needs of city and rural health officers.

Only a few of the many papers presented will be mentioned here. Dr. Eugene H. Porter, State Commissioner of Health, gave an address on "What a Health Department Expects from Municipal Authorities." He urged mutual understanding between the board of health and the governing body of the municipality and that parsimony in appropriations be avoided. He stated that politics must be drummed out of every city, state and national health department. He urged that sanitary science and public health be taught in all the schools.

Mr. Charles C. Duryee, Mayor of Schenectady, discussed health matters from the standpoint of the municipal officer. He remarked that the spectacle of the mayors of 42 out of 49 cities meeting together last summer to discuss questions relating to the health of cities was encouraging. The health officer of to-day, he said, is a leader and creator of public opinion. He was of the opinion that health departments deserve a much larger proportion of municipal funds than they receive.

At an evening meeting open to the public the leading address was by Dr. C. A. Hodgetts, Medical Adviser to the Commission of Conservation, Ottowa, Ont. The subject of the address was "Public Health and the Conservation Movement." The speaker asked whether the time had not come for a national stock taking which would determine the value of human as well as agricultural resources. Property is now given more consideration than human life. The speaker drew a glowing picture of a public-health millenium. At some future time preventative medicine will become more important than curative.

The Canadian Conservation Commission has been officially created by the Canadian government and been given an appropriation of $50,000. It is to make a study and inventory of the natural resources of Canada. A committee on health has been appointed. Already a conference has been held with the health officers of the various provinces and such a conference will be held annually hereafter.

Dr. Hodgett was followed by Col. Francis G. Ward, Commissioner of Public Works of Buffalo, who had been assigned the topic "Public Health and the Public Purse." The address consisted chiefly of a review of some of the sanitary engineering works of Buffalo, in particular the disposal of garbage and refuse. The garbage is treated at a reduction plant. Mixed refuse is taken to a sorting and burning plant, where material of commercial value is recovered for sale. The combustible tailings go to a Heenan & Froude refuse destructor. During the past three years the sorting and burning plant has been operated at a net profit of $8,080. For the year ending last July the plant was credited with $2,802 for steam used by the low-level sewage pumping station. During the course of his remarks Colonel Ward said that the city of Buffalo expects to meet the desires of the State Department of Health regarding sewage disposal by building a screening and sedimentation plant.

At a session for city health officers a paper on garbage disposal was read by Dr. P. M. Hall, Health Officer of Minneapolis. The garbage of the city named is wrapped in paper by householders, deposited in watertight metal cans, and removed from the houses in wagons with detachable metal boxes. At the garbage furnace the boxes are lifted by an electric hoist and dumped directly into the furnace. The steam generated by the furnace operates the machinery of the garbage plant and provides heat and light for the plant, for the house of the superintendent, for a tuberculosis hospital and for two greenhouses. The gross cost of garbage collection and disposal in 1909 was about 19½ cts. per capita, including also the cost of removing ashes.

In connection with the discussion on this paper it was stated that one of the smaller cities of New York has recently made an arrangement by which a private contractor collects and disposes of all garbage and charges each householder a weekly fee of 10 cts. for the service. This includes washing the cans. Duplicate cans are provided, each about 14 ins. in diameter and about 20 ins. high. The garbage is collected weekly in wagons holding 52 cans, a clean can being left at each house. Each householder makes a deposit of $2 for his cans. The garbage is boiled and fed to hogs.

Among the many papers presented may be mentioned one on "City Sanitation," by Prof. Charles Baskerville, of the College of the City of New York; "The Control of Typhoid Fever," by Dr. H. W. Grill, Director Epidemiological Division, Minnesota State Board of Health, Minneapolis, and "Unattacked Communicable Diseases," by Dr. Gardner Swarts, Secretary State Board of Health, Providence, R. I.

MUNICIPAL ENGINEERS OF NEW YORK. A subject of unusual interest was discussed at the meeting of Nov. 23, held in the Engineering Societies' Building, New York City. Col. William M. Black, Corps of Engineers, U. S. A., presented a paper on the subject "Problems of Sewage Disposal in New York," which related to the attempts being made for some time past to determine the factors involved in the pollution of New York Harbor by the city's sewage and the possibilities in the way of other disposal than direct discharge of crude sewage into the rivers and the harbor.

Col. Black began with the premise that the Hudson and East rivers and the harbor are seriously polluted. As a gage of pollution he takes the amount of dissolved oxygen in the water. Finding the normal amount of oxygen in unpolluted fresh water and sea water respectively, he assumes arbitrarily that when the oxygen is reduced to 70% of the normal value the limit of permissible pollution has been reached. At this point, he says, major fish life decreases or disappears. This limit is passed in New York Harbor. He discussed further at considerable length the complex relations of the tidal movements from Long Island Sound and from the Sandy Hook entrance of New York Bay, and brought together a great amount of information on tidal periods, velocity of flow, and net translation of water. The action of tidal movements and their effect upon sewage dilution and resultant pollution of water was also studied quite thoroughly in relation to Jamaica Bay, which is expected in future to become a very important commercial basin. The possibilities of sewage purification by sprinkling filters were briefly touched upon, and the author stated that, according to the indications of experiments, forced aeration of the beds would give a very great increase of filtering capacity. The prospects for purification of New York's sewage were not put into a very promising light, however, by the paper.

On the question of direct discharge of sewage into sea water, the author referred to Boston, Washington and elsewhere and to the Passaic Valley Sewerage District outfall, soon to be constructed in the upper bay at New York. He showed that a horizontal and distributed discharge was necessary to produce proper dissemination of the outflow—a result which is not being obtained at Boston, for example, where the outlet discharges vertically upward at considerable velocity. A demonstration apparatus was shown in operation to exhibit the disseminating effect of the horizontal discharge. Important experimental work, now in progress for the City of New York, was briefly mentioned, including as one of its items tests to determine the rate at which re-aeration of water takes place. It was stated that the old assumption, that the absorption of air at the surface of water is quite marked and rapid, has been proved wrong and that the absorption is in fact exceedingly slight, so that most of the renewal of oxygen in the water must come about in other ways.

The paper was discussed in thorough fashion by Mr. Rudolph Hering, who directed his first criticisms against the assumption as to the limit of oxygen reduction which may be permitted in water. By referring to numerous examples of actual waters where no objectionable conditions existed, he showed that if there is a specific limit to permissible oxygen reduction it is far lower than the author's 30%. Mr. Allen Hazen, in discussing this same point, took the same ground quite as strongly and, in fact, stated that his own experiments and observations proved that the oxidizing action in water goes on at practically an undiminished rate so long as there is any oxygen left in the water at all—hence that the permissible limit of oxygen reduction is only reached when practically all the oxygen in the water is consumed. By referring to waters where the oxygen is reduced to as low as 5% of normal, he made it clear that the 70% limit is not in accord with practice elsewhere.

The question of re-aeration of water from the surface was also taken up both by Mr. Hering and by Mr. Hazen, and they agreed in substance in holding that experience proves re-aeration to go on very rapidly. Mr. Hering referred in some detail to the new sewage treating tank developed in Germany, the Imhoff tank, and held out a prospect of finding in this device a solution of the sewage disposal problem far in advance of any device hitherto existing. The broader subject of what is the proper attitude toward disposal of sewage by discharge into streams and other natural waters gave occasion to Mr. Hering, Mr. Hazen and also Mr. Emil Kuichling to come out in advocacy of the practice of using streams as sewage carriers, when done properly. The general result of the discussion was to throw very strong doubt on the assumption, made by some, that the waters of New York Harbor are seriously polluted and the further assumption that such pollution as exists can be abolished only by complete purification of the sewage prior to discharge. This touches directly the work of the Metropolitan Sewerage Commission, a State body which is now dealing with the harbor pollution. Dr. George A. Soper, of the Commission, who was present, did not, however, enter into a discussion of the paper. The investigations and studies recorded by Col. Black were being done for the city authorities directly, without any connection with the Sewerage Commission.